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## CONTENTS

|                                                                                                | Page |
|------------------------------------------------------------------------------------------------|------|
| Dr. Friedrich-Wilhelm Kremer:                                                                  |      |
| Studies on the Biology, Epidemiology and Control<br>of <i>Bryobia praetiosa</i> Koch . . . . . | 189  |

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## Studies on the Biology, Epidemiology and Control of *Bryobia praetiosa* Koch

by Dr. Friedrich-Wilhelm Kremer

### Contents

|                                                                               | Page |
|-------------------------------------------------------------------------------|------|
| Introduction . . . . .                                                        | 190  |
| I. Systematic classification and nomenclature . . . . .                       | 191  |
| II. Morphology . . . . .                                                      | 193  |
| III. Geographical propagation . . . . .                                       | 195  |
| IV. Host plants . . . . .                                                     | 195  |
| V. Occurrence in relation to type of tree and degree of cultivation . . . . . | 197  |
| VI. Damage and nature of injuries inflicted . . . . .                         | 199  |
| VII. Biology . . . . .                                                        | 200  |
| A. Emergence of the larvae from the winter eggs . . . . .                     | 200  |
| 1. Emergence of larvae from winter eggs in outdoor conditions . . . . .       | 200  |
| 2. Pre-determination of the hatching date . . . . .                           | 203  |
| 3. Date of hatching and percentage of hatching . . . . .                      | 205  |
| a) Relation to exposure to light . . . . .                                    | 205  |
| b) Relation to relative humidity . . . . .                                    | 206  |
| c) Relation to temperature . . . . .                                          | 207  |
| B. Development of the post-embryonic stages . . . . .                         | 209  |
| 1. Influence of temperature . . . . .                                         | 209  |
| a) Period of development of the post-embryonic stages . . . . .               | 209  |
| b) Length of the pre-ovipositional period . . . . .                           | 213  |
| c) Effect of extremely high temperatures . . . . .                            | 214  |
| 2. Influence of moisture . . . . .                                            | 215  |
| C. Summer oviposition . . . . .                                               | 216  |
| 1. Location of oviposition . . . . .                                          | 216  |
| 2. Number of eggs . . . . .                                                   | 217  |
| 3. Duration of embryonic development . . . . .                                | 218  |
| D. Winter oviposition . . . . .                                               | 220  |
| 1. Location of oviposition . . . . .                                          | 221  |
| 2. Number of eggs . . . . .                                                   | 222  |
| E. Behaviour of mites on the plants . . . . .                                 | 222  |
| VIII. Epidemiology . . . . .                                                  | 224  |
| A. Number and temporal occurrence of generations . . . . .                    | 224  |

|                                                                                                                                     |     |
|-------------------------------------------------------------------------------------------------------------------------------------|-----|
| B. Change in population density . . . . .                                                                                           | 229 |
| 1. Weather and change in population density . . . . .                                                                               | 229 |
| 2. Occurrence and importance of predators . . . . .                                                                                 | 232 |
| 3. Characteristics of the change in population density of <i>Br. praetiosa</i><br>compared with other spider mite species . . . . . | 235 |
| C. Plant hosts as infectors for the colonization of fruit trees by <i>Br. praetiosa</i> . . . . .                                   | 236 |
| IX. Control . . . . .                                                                                                               | 239 |
| A. Dates of control . . . . .                                                                                                       | 240 |
| B. Trial controls of the egg stage . . . . .                                                                                        | 242 |
| 1. Winter eggs . . . . .                                                                                                            | 242 |
| 2. Summer eggs . . . . .                                                                                                            | 243 |
| C. Trial controls of post-embryonic stages . . . . .                                                                                | 245 |
| X. Summary . . . . .                                                                                                                | 246 |
| Literature . . . . .                                                                                                                | 248 |

## Introduction

*Bryobia praetiosa* Koch, along with *Paratetranychus pilosus* Can. et Fanz. and *Tetranychus althaeae* v. Hanst., is from the economical aspect, one of the most important spider mite species. The increased infestation of our cultivated plants by spider mites during recent years was the reason for studies being made on the biology, epidemiology and control of this particular pest species. Similar studies have already been conducted in respect of *P. pilosus* and *Tetr. althaeae* (Listo, 1939; Andersen, 1948; Gasser, 1951; Dosse, 1952; Linke, 1953).

Only single observations have been made in the past on *Br. praetiosa*, which do not provide a clear picture of the biology, epidemiology and control of the pest. In fact, the data available have often proved to be contradictory, probably because the biology and epidemiology of *Br. praetiosa* vary dependent upon the groups of plant hosts. My studies have been chiefly confined to the species occurring on deciduous fruit. In addition to making observations of the natural development of this species outdoors, I have attempted to complete our knowledge of its biology by clarifying the relations existing between the development of the different stages and the temperature, relative humidity and light conditions. With respect to the epidemiological aspect, I gave attention to the population-dynamic factors in order to obtain some form of guide for predicting the development of gradation, and also to provide a contribution towards clarifying the question of the causes for the growing infestation of spider mites. In order to gain information on the possibility of carrying out a combined control of *Br. praetiosa* and *P. pilosus*, I often included the latter species in my studies for comparison purposes.

The investigations were conducted at the Field Research Station, Höfchen which is situated approximately 650 feet above sea level on a range of hills in Bergische Land, some 12 miles north-east of Cologne. The mean annual rainfall is between 3 and 4 inches.



## I. Systematic classification and nomenclature

The systematic classification of *Bryobia praetiosa* is as follows:

|          |                       |           |
|----------|-----------------------|-----------|
| Class    | <i>Arachnoidea</i>    |           |
| Order    | <i>Acari</i>          |           |
| Suborder | <i>Trombidiformes</i> | Reuter    |
| Family   | <i>Tetranychidae</i>  | Donnadieu |
| Genus    | <i>Bryobia</i>        | Koch      |
| Species  | <i>Br. praetiosa</i>  | Koch      |

The common name "Stachelbeermilbe" (gooseberry mite) under which the species is known in Germany, has apparently been selected at random just like the name "clover mite" which is common in America, and not out of consideration for the chief plant host.

The difficulties experienced in obtaining anatomical and morphological data, due to the minute size of spider mites, are undoubtedly the reason for synonyma being given for *Br. praetiosa*, just as for other Tetranychidae. Thomas (1896) referred to the species he observed on gooseberries as *Br. ribis* because he was unable to check the description Koch (1836 and 1838) gave for the species he determined (*Br. praetiosa*; *Br. speciosa*; *Br. nobilis*). Zacher (1913) assumed that *Br. ribis* Thomas on gooseberries and *Br. praetiosa* Koch on apples and ivy, are identical. He wrote in 1916 that his assumption was confirmed by Trägårdh who also established that the name *Br. pratensis* Garman, given to the clover mite occurring in the U.S.A., is a synonym of *Br. praetiosa*. Oudemans (1929) of Holland also arrived at the conclusion that *Br. ribis* is identical with *Br. praetiosa*. During the past ten years, reference is made in the literature to the name *Br. praetiosa* in practically all cases.

The synonyma are, therefore, as follows:

*Bryobia praetiosa* Koch  
*Bryobia speciosa* Koch  
*Bryobia nobilis* Koch  
*Bryobia ribis* Thomas  
*Bryobia pratensis* Garman

It appears that an endeavour has been made during recent years to classify *Bryobia* into different species according to the plant hosts on which they occur. Van Eynhoven (1955) described the *Bryobia praetiosa* form occurring on ivy as *Bryobia kissophila* v. Eynhd. on the basis of morphological differences which he established. Once he has clarified questions appertaining to nomenclature, he also intends to introduce specific names for the forms occurring on apples and pears.

The question as to whether the spider mites classified today under the name of *Br. praetiosa* belong to one or several species, or whether they are strains of one and the same species, will have to be settled by means of systematic investigations.

In my studies, I have used the name which is at present commonly referred to in the literature as *Bryobia praetiosa* Koch.

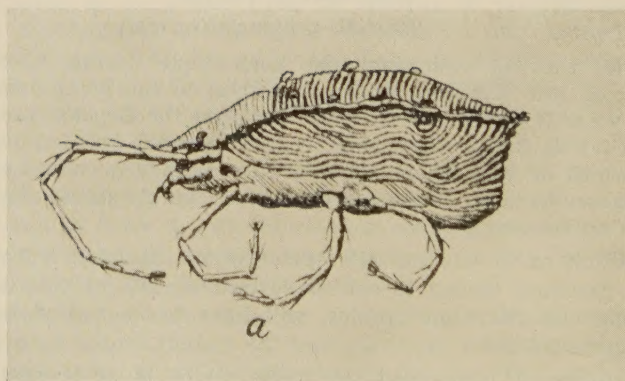
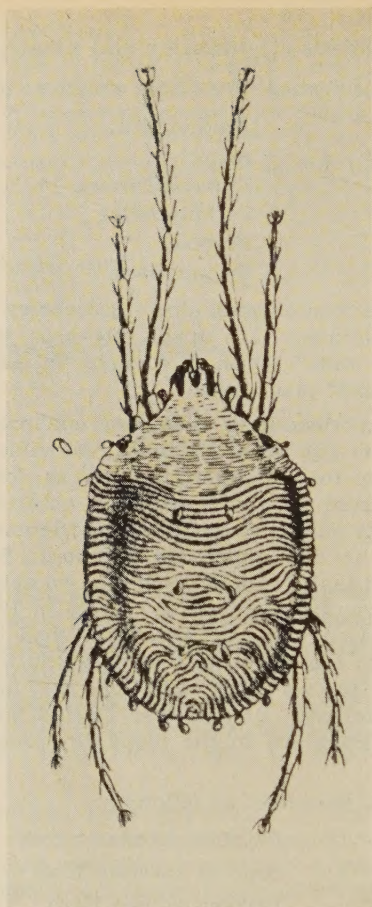


Fig. 1: Imago of *Br. praetiosa*. Magnification  $\times$  approx. 100 (Thomas)



## II. Morphology

It is not possible to differentiate between thorax and abdomen on *Br. praetiosa*. The body can merely be subdivided into two sections by the transverse groove running behind the second pair of legs, namely into the proterosoma with the mouth parts and the two front pairs of legs, and the hysterosoma with the two backward pairs of legs (Fig. 1). The front edge of the proterosoma is divided into four lobes with a hair on each. Beneath these are the piercing-sucking mouth extremities. On each side of the proterosoma are two red stemmata. The legs each consist of six segments covered with hairs, and the tarsi are well developed. Special characteristics are the first long pair of legs, and the clavate hair covering of the flattened body which has a pronounced stepped edge on its dorsal side. These features facilitate easy distinction of *Br. praetiosa* from other Tetranychidae.

The mite passes through eight different stages in its development from the egg to the imago. These stages are as follows: egg, larva, nymphochrysalis (1st quiescent stage), protonymph, deutochrysalis (2nd quiescent stage), deutonymph, teliochrysalis (3rd quiescent stage), imago (Fig. 2).

The egg of *Br. praetiosa* differs greatly in its shape, colour and size from the egg of *P. pilosus*. Whereas the winter eggs of *P. pilosus* are flattened, carmine-red in colour, and have a radial groove, the eggs of *Br. praetiosa* are spherical, dark-red and have a perfectly smooth surface. They are 0.17 mm large. Morphologically, there are no differences between the winter and summer eggs of *Br. praetiosa*. The colour and shape hardly change during embryonic development, and it is only immediately prior to hatching that the egg assumes a dull whitish colour due to infiltration of air between the egg shell and the fully developed larva.

Shortly after hatching out, the larva has an orange-red colour. The more food it consumes, the greener will be the colour of the body. On the average it is  $0.24 \times 0.17$  mm\* in size. The only development it makes in this stage is to form three pairs of legs. After a certain period, the larva passes into the 1st quiescent stage from which the protonymph develops.

The protonymph differs from the larvae in its size which has now increased to  $0.31 \times 0.22$  mm, and also in the fact that it has four pairs of legs. The colour which at first is brown, changes to greenish-brown as the consumption of food increases. The protonymph is followed by the 2nd quiescent stage from which the deutonymph develops.

The deutonymph is 0.42 mm long and 0.30 mm wide. Its colour, too, varies according to the consumption of food, and changes from brown to greenish. During this stage it is possible to differentiate between males and females of numerous Tetranychidae. *Br. praetiosa* has no males. The deutonymph is followed by the 3rd quiescent stage from which the imago develops.

The imago measures  $0.60 \times 0.45$  mm. At first it is brown in colour being influenced by the consumption of food although not to the same extent as in the pre-imaginal stages. The brown colour becomes more pronounced as the mite grows older. The imago is characterized by a very strongly developed

\* The sizes were determined by means of an ocular micrometer, and represent the average of ten measurements. The length includes the mouth parts.

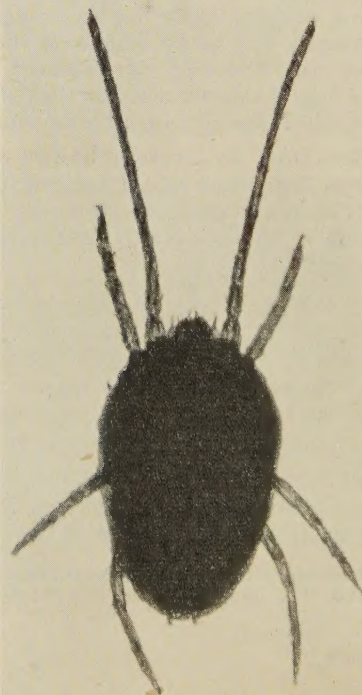
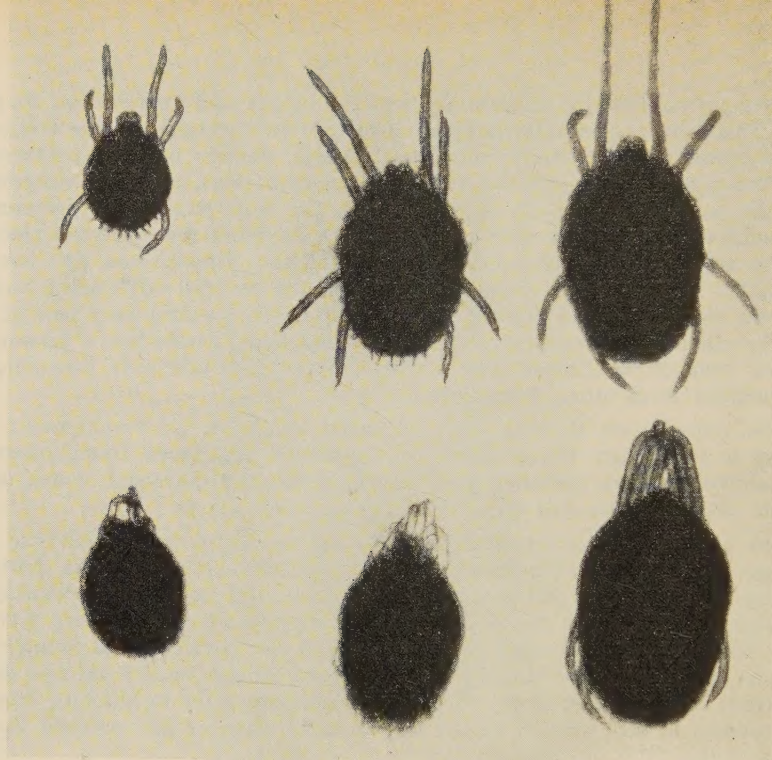


Fig. 2:  
Development stages of *Br. practiosa*

Top row:

Larva, protonymph,  
deutonymph

Second row:

1st quiescent stage

2nd quiescent stage

3rd quiescent stage

Bottom: Imago

Magnification  $\times 70$



first pair of legs. Reproduction is parthenogenetic, and only females emerge from the eggs. Accordingly, *Br. praetiosa* displays constant thelytoky. It belongs to the non-spinning Tetranychidae.

The dormant stages following the larval and the nymphal stages have a characteristic posture. The long, first pair of legs is folded together underneath so that it appears to be greatly shortened. The hind pair of legs lies flat against the body. After a certain period of quiescence has elapsed, air enters between the moulting skin and the new development stage. As a result, the quiescent stage assumes a silvery-white appearance. Finally the skin bursts on the top surface of the quiescent stage, and the nymph or the imago appears.

### III. Geographical propagation

The main region of propagation for *Br. praetiosa* is in the moderate zones, although it also occurs in the sub-tropical zones.

In Europe, the incidence of *Br. praetiosa* extends from Norway, Sweden and Finland in the North, down to Italy and Spain in the South. It also occurs in England and Scotland, whereas it is not known to occur in the countries of Eastern Europe.

In North America, it is spread over wide areas of the U.S.A. and in the southern part of Canada. With respect to South America, there are reports on the incidence of *Br. praetiosa* in Columbia and the Argentine, while on the African Continent it is known to occur in South Africa, Morocco and Egypt. Reports of its occurrence in Australia have been received from all states, including Tasmania and New Zealand.

### IV. Host plants

During 1954 and 1955, *Br. praetiosa* was found on the following plants in the Rheinisch-Bergisch District:

- |               |                                   |
|---------------|-----------------------------------|
| 1. Apple      | <i>Malus</i> varieties            |
| Pear          | <i>Pirus</i> varieties            |
| Gean          | <i>Prunus avium</i> varieties     |
| Plum          | <i>Prunus domestica</i> L.        |
| Peach         | <i>Prunus persicae</i> Stokes     |
| Apricot       | <i>Prunus armeniaca</i> L.        |
| Buckthorn     | <i>Prunus spinosa</i> L.          |
|               | <i>Malus Scheidekeri</i> Zabel    |
| 2. Gooseberry | <i>Ribes grossularia</i> L.       |
| Red Currant   | <i>Ribes rubrum</i> L.            |
| Black Currant | <i>Ribes nigrum</i> L.            |
| 3. Hawthorn   | <i>Crataegus monogyna</i> Jacquin |
| Red thorn     | <i>Crataegus oxyacantha</i> L.    |
| 4. Ivy        | <i>Hedera helix</i> L.            |

|                    |                                 |
|--------------------|---------------------------------|
| 5. Cock's foot     | <i>Dactylis glomerata</i> L.    |
| Tall Oat-grass     | <i>Avena elatior</i> L.         |
| Shewing Fescue     | <i>Festuca rubra</i> L.         |
| Common Rye-grass   | <i>Lolium perenne</i> L.        |
| Creeping Buttercup | <i>Ranunculus repens</i> L.     |
| Common Vetch       | <i>Vicia cracca</i> L.          |
| White Clover       | <i>Trifolium repens</i> L.      |
| Purple Loosestrife | <i>Lythrum salicaria</i> L.     |
| Cow Parsnip        | <i>Heracleum sphondyleum</i> L. |
| Burnet Saxifrage   | <i>Pimpinella saxifraga</i> L.  |
| Wild Angelica      | <i>Angelica silvestris</i> L.   |
| Bishop's Weed      | <i>Aegopodium podagraria</i> L. |

These species can be summarized in the five separate groups listed, to which reference will be made in greater detail later (cf. VIII. C.).

This range of plant hosts to *Bryobia praetiosa* can be extended even more by quoting data given in the literature:

|                  |                                     |
|------------------|-------------------------------------|
| Poplar           | <i>Populus</i> sp.                  |
| Walnut           | <i>Juglans regia</i> L.             |
| Oak              | <i>Quercus</i> sp.                  |
| Elm              | <i>Ulmus</i> sp.                    |
| Buckwheat        | <i>Fagopyrum sagittatum</i> Gil.    |
|                  | <i>Ribes alpinum</i> L.             |
| Almond           | <i>Prunus amygdalus</i> Batsch.     |
| Raspberry        | <i>Rubus idaeus</i> L.              |
| Bramble          | <i>Rubus fruticosus</i> L.          |
| Strawberry       | <i>Fragaria</i> sp.                 |
| Alfalfa          | <i>Medicago sativa</i> L.           |
| Red Clover       | <i>Trifolium pratense</i> L.        |
| Castor-oil Plant | <i>Ricinus communis</i> L.          |
| Citrus           | <i>Citrus</i> sp.                   |
| Grape Vine       | <i>Vitis vinifera</i> L.            |
| Violet           | <i>Viola</i> sp.                    |
| Bindweed         | <i>Convolvulus</i> sp.              |
| Butterbur        | <i>Petasites officinalis</i> Moench |
| Narcissus        | <i>Narcissus</i> sp.                |
| Wheat            | <i>Triticum aestivum</i> L.         |
| Barley           | <i>Hordeum vulgare</i> L.           |
| Oats             | <i>Avena sativa</i> L.              |
| Timothy          | <i>Phleum pratense</i> L.           |
| Sugar            | <i>Saccharum</i> sp.                |

In addition, data of a general nature are also given in the literature on the occurrence of *Br. praetiosa* on vegetables, mosses and grasses. In Europe and in the U.S.A., the mites migrated from parks and infiltrated into dwelling houses, thus developing into a most unpleasant house plague.

## V. Occurrence in relation to type of tree and degree of cultivation

In addition to the population density, the varying degree of incidence of the species in orchards of different density also has a bearing upon the economic significance of the different spider mite species. Unterstenhöfer (1955) points out that *Br. praetiosa* occurs chiefly on standards and that the greatest incidence of *P. pilosus* is to be found on bush trees, basing his assertions on observations he made in 62 standard and bush plantations in the Rhine area.

I investigated the occurrence of both species in relation to the type of tree and the degree of cultivation, on the basis of the incidence of winter eggs laid by *Br. praetiosa* and *P. pilosus* in 330 orchards. In these investigations, I differentiated between standard and bush orchards, on the one hand, and between cultivated and non-cultivated orchards, on the other hand. Cultivated orchards were understood to be those in which pruning and pest controls were carried out regularly. If no pruning and no pest controls were carried out, the orchard was assessed as being non-cultivated.

Table 1: Occurrence of *Br. praetiosa* and *P. pilosus* in relation to the type of tree and the degree of cultivation.

|                 | Total No. of<br>orchards<br>examined | <i>Br. praetiosa</i> |    | Chiefly<br><i>Br. praetiosa</i> |    | Chiefly<br><i>P. pilosus</i> |    | <i>P. pilosus</i> |    |
|-----------------|--------------------------------------|----------------------|----|---------------------------------|----|------------------------------|----|-------------------|----|
|                 |                                      | abs.                 | %  | abs.                            | %  | abs.                         | %  | abs.              | %  |
| <b>Standard</b> |                                      |                      |    |                                 |    |                              |    |                   |    |
| cultivated      | 36                                   | 8                    | 22 | 14                              | 39 | 11                           | 31 | 3                 | 8  |
| non-cultivated  | 166                                  | 66                   | 40 | 88                              | 53 | 10                           | 6  | 2                 | 1  |
| <b>Bush</b>     |                                      |                      |    |                                 |    |                              |    |                   |    |
| cultivated      | 96                                   | 0                    | 0  | 1                               | 1  | 20                           | 21 | 75                | 78 |
| non-cultivated  | 32                                   | 2                    | 6  | 6                               | 19 | 19                           | 59 | 5                 | 16 |

The results given in Table 1 serve to confirm the observation of Unterstenhöfer (1955) that *Br. praetiosa* is the typical pest of our standard orchards, and *P. pilosus* that of our bush orchards. In cultivated orchards there is a strong recession of *Br. praetiosa* infestation, whereas the occurrence of *P. pilosus* increases. Older trees were very seriously infested by *Br. praetiosa*.

Summers and Baker (1952) observed the varying incidence of *Br. praetiosa* in relation to the surface state of the branches. My own investigations confirmed that trees with rough, split barks were very seriously infested. This form of surface condition preferred by *Br. praetiosa* is to be found in non-cultivated orchards, particularly where standards are growing, and is in keeping with the habits of *Br. praetiosa*, a species which after all migrates between



leaves and branches, and which hides in bark cracks and recesses in branches where it also seeks protection from rainfall (cf. VII. E.). M a s s e e (1954) reports as the cause of a serious infestation of *Br. praetiosa* on pears growing along a stone wall, that the mites could seek protection in cracks in the wall during unpleasant, rainy periods of weather. In addition, *Br. praetiosa* is more sensitive to moisture than *P. pilosus* (cf. VII. B. 2.). *Br. praetiosa* is affected to a



Fig. 3: Sucking injuries inflicted by *Br. praetiosa* on the upper leaf surface.  
Left: seriously injured. Right: uninjured. (Orig.)

far greater extent by wind and rain on the smooth branch surfaces of open tree tops in cultivated bush orchards than the mites of *P. pilosus* which remain on the lower surfaces of the leaves. The different state of the bark, therefore, explains quite simply why there is varying occurrence of both species in orchards which differ in their type of trees and degree of cultivation.

"Rote Sternrenette", "Boskoop", "Berlepsch", "Zabergäurennette" and "Winter-Goldparmäne" were the varieties most seriously infested by *Br. praetiosa*.

## VI. Damage and nature of injuries inflicted

The larvae emerging from the winter eggs in Spring, immediately migrate to the buds and the first leaves, and begin to consume nutrition.

The nature of the injury inflicted changes during the course of the vegetation period. At first, the mites by their sucking activities cause whitish-grey spots, not sharply defined, on the upper surface of young leaves, chiefly close to the base of the veins. As the rate of infestation increases and the season

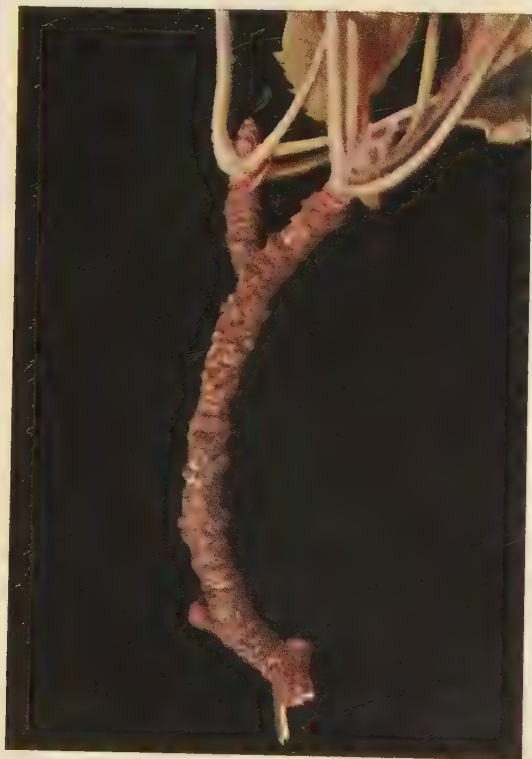


Fig. 4: Empty skins of quiescent stages on the lower branch surface. (Orig.)

continues, the injury spreads over the whole leaf so that in the end it is much lighter in colour than the non-infested leaf (Fig. 3). The bronzing of the leaves so typical of *P. pilosus* attacks, is not to be found following *Br. praetiosa* infestation, which leads to the conclusion that both species have different enzymatic processes. The leaves seriously injured by *Br. praetiosa* retain their greenish-grey colour until leaf fall. The leaves which emerge first in Spring are very strongly discoloured and do not grow to their normal size.

In contrast to *P. pilosus*, hardly any empty skins of the quiescent stages are to be found on the leaves, although there are large numbers of them on

the branches close to the growing points of the leaves (Fig. 4). With high rates of incidence, the entire lower surface of the branch is covered with a thick, white layer of empty skins.

*Br. praetiosa* pierces the cuticle and epidermis of the leaves with its stiletto-like mandibles, and sucks out the contents of the cell located underneath. Consequently, anabolic substances are taken from the plant, on the one hand, and the assimilation surface is reduced due to destruction of the cells, on the other hand. Both conditions are accompanied by a weakening of the vegetative organs, premature leaf fall, formation of small, non-matured fruit, and yield losses in the following year.

## VII. Biology

In the studies on the biology of the pest, attention was focussed on the influence exerted by abiotic factors upon the development of the post-embryonic stages and the eggs, and also on the behaviour of *Br. praetiosa* in natural environmental conditions. Insofar as the methodical possibilities permitted, field tests were conducted, and these were augmented by laboratory tests to ensure the reliability of the results.

### A. Emergence of the larvae from the winter eggs

#### 1. Emergence of larvae from winter eggs in outdoor conditions

Data published in the pertinent literature already indicate that the commencement of hatching of *Br. praetiosa* depends upon the prevailing climatic conditions. In Norway, *Br. praetiosa* hatches out in May and June (Fjeldalen 1952), in Belgium in April (Wybecu 1951), in the Pfalz in March (Roesler 1952) and in the region of Lyons at the end of March (Tissot and Ferand 1954). It is, therefore, evident that hatching starts earlier in the southern countries of Europe than in the North.

Table 2 gives the dates when *Br. praetiosa* started to hatch in the years from 1952 to 1955 at the Höfchen Research Station. The corresponding dates are also given in respect of *P. pilosus* by way of comparison.

Table 2: Commencement of hatching for *Br. praetiosa* and *P. pilosus* 1952—1955.

|      | Commencement of hatching |                   | Average temperature expressed<br>in °C from January 1st until<br><i>Br. praetiosa</i> commenced<br>hatching |
|------|--------------------------|-------------------|-------------------------------------------------------------------------------------------------------------|
|      | <i>Br. praetiosa</i>     | <i>P. pilosus</i> |                                                                                                             |
| 1952 | April 10                 | April 14          | 2.12                                                                                                        |
| 1953 | April 8                  | April 18          | 2.22                                                                                                        |
| 1954 | April 18                 | May 3             | 1.9                                                                                                         |
| 1955 | April 27                 | May 2             | 0.87                                                                                                        |



According to the tabulated data, *Br. praetiosa* hatched out in April under the climatic conditions prevailing at the Höfchen Research Station.

The calculation of the average temperature from the daily means which were recorded by the Meteorological Section of the Höfchen Research Station for the period from January 1 until *Br. praetiosa* commenced hatching, revealed that the temperatures prevailing from January onwards obviously have a great bearing upon the date of hatching. At the high average temperatures in 1953, *Br. praetiosa* hatched out on April 8 whereas hatching did not commence until April 27 at the low temperatures prevailing in 1955. The comparison of the minimum and maximum temperatures and the date of hatching led to the same result.

The larvae of *P. pilosus* began to emerge 4 to 15 days later than those of *Br. praetiosa* during the years of study. The more rapid sequence at which both species commenced hatching in 1952 and 1955 was due to the fact that in 1952 (from April 10 to 14) there was a mean daily temperature of 17.88 °C, and in 1955 (from April 27 to May 2) a mean daily temperature of 15.58 °C, as compared with 8.43 °C and 9.11 °C in 1953 (April 8 to 18) and 1954 (April 18 to May 3) respectively. As a rule, it may be taken that *P. pilosus* hatches out approximately 1 to 2 weeks later than *Br. praetiosa*.

In Table 3, the dates for the end of hatching and the commencement of summer egg-laying during 1954 and 1955 are given in addition to the start of hatching.

Table 3: Hatching dates and the commencement of summer egg-laying for *Br. praetiosa* and *P. pilosus* in 1954 and 1955.

| <i>Br. praetiosa</i>        |                    |                                  | <i>P. pilosus</i>           |                    |                                  |
|-----------------------------|--------------------|----------------------------------|-----------------------------|--------------------|----------------------------------|
| Commencement<br>of hatching | End of<br>hatching | Start of<br>summer<br>egg-laying | Commencement<br>of hatching | End of<br>hatching | Start of<br>summer<br>egg-laying |
| 1954 April 18               | May 2              | May 18                           | May 3                       | May 26             | May 17                           |
| 1955 April 27               | May 2              | May 29                           | May 2                       | May 20             | May 30                           |

As the fruit blossom continued from May 8 to 23 in 1954 and from May 8 to 25 in 1955, the larvae of *Br. praetiosa* had all emerged before the blossom in both years, whereas *P. pilosus* hatched out chiefly during the blossom. Despite the difference in the dates when the two species started to hatch out, they both commenced laying their summer eggs at practically the same time because the postembryonic stages of *Br. praetiosa* develop more slowly (cf. VII. B. 1. a.). In 1954, both species began to lay their summer eggs during the blossom, and in 1955 after the blossom.

In both years, the exact progress of larval emergence from the winter eggs was kept under observation.

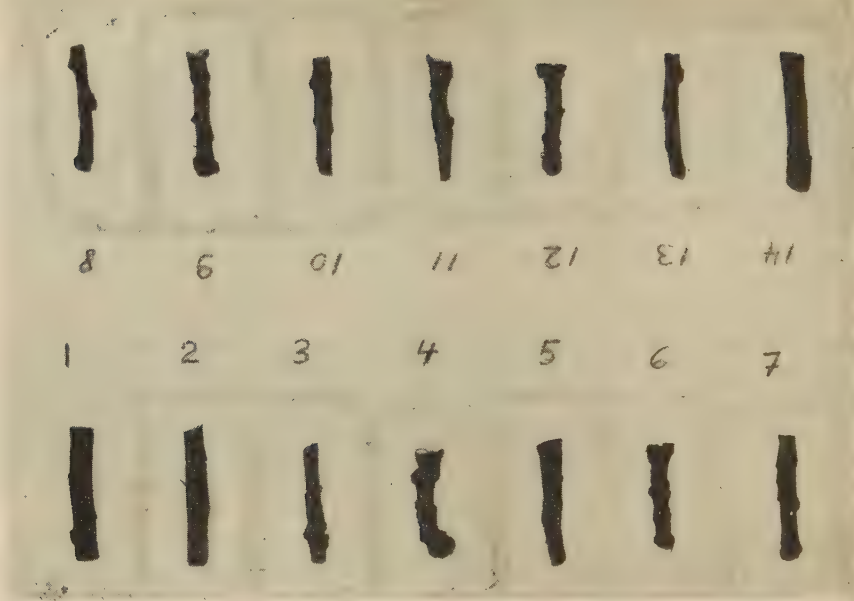


Fig. 5: Pieces of branches colonized by winter eggs, glued to a wooden board and surrounded by a ring of vaseline

**Method:** Sections of branches colonized by winter eggs of *Br. praetiosa* were split lengthwise, glued on a wooden board and surrounded by a ring of vaseline to prevent freshly emerged larvae from migrating (Fig. 5). To make as much allowance as possible for natural conditions, the boards bearing the sections of branches were placed on the fruit trees outdoors in such a manner that the eggs were only exposed to the sun for a short period. The emerged larvae, some of which were caught in the vaseline attempting to migrate from the pieces of branches while others remained on the branches, were counted twice daily under the binocular lens. The emerged larvae were removed with a needle. By carrying out a check, it was established that the larvae on the branches of the trees and those on the boards emerged simultaneously.

This method proved to be most effective in carrying out studies on the eggs of *Br. praetiosa*. It was possible not only to take an exact count of the larvae which hatched out daily but also to determine most reliably the percentage of hatching by counting the number of larvae which did not emerge.

Figure 6 illustrates the relation of hatching to the mean daily temperature. The average temperature from the commencement until the end of hatching was  $8.56^{\circ}\text{C}$  in 1954 (April 18 to May 2) and  $15.58^{\circ}\text{C}$  in 1955 (April 27 to May 2). The result was that the hatching out process of larvae from winter eggs continued for 14 days in 1954 whereas in 1955 all the larvae had emerged within only five days. Rising temperatures caused an increase in the number of larvae hatched out daily during both years. In 1954, most of the larvae had emerged from the winter eggs by April 29 so that the high temperatures prevailing on April 30 and May 1 did not cause a further increase in the number of larvae hatching out daily.

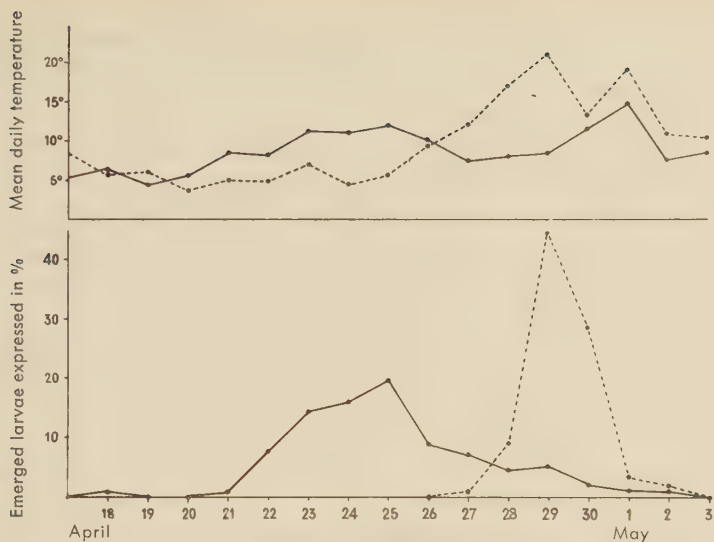


Fig. 6: Hatching out of larvae from winter eggs  
 — 1954  
 - - - 1955

The percentage of hatching in 1954 was  $85.6 \pm 3.7$ , and in 1955 it was calculated at  $86.8 \pm 3.3$  \*. The only eggs included in the studies were those from which no larvae emerged in Spring, but not those which were killed by predators during the Autumn and Winter months.

## 2. Pre-determination of the hatching date

The pre-determination of the date when a pest will begin to hatch out may be of great importance for carrying out control measures, because it can facilitate the timely application of pesticides and contribute to limiting the number of sprays to a minimum. Schneider and Vogel (1950) point out that the success of controls carried out against the cherry fruit fly, *Rhagoletis cerasi*, depend largely upon a correct forecast of the date when hatching will begin. They have evolved a method which enables the development stage of the pupae and the presumable date when the flies will start to hatch out, to be determined in good time.

A question of fundamental interest is whether it is also possible to forecast the date of hatching for spider mites. The answer to this question was intended to provide a contribution towards clarifying problems relating to forecasts. Moreover, the pre-determination of the hatching date might prove to be of practical importance also for these pests. Grob (1951) and Unterstenhöfer (1955) emphasize that *Br. praetiosa* and *P. pilosus* inflict the greatest

\* The mean error was calculated according to the formula generally applied:

$$m = \pm \sqrt{\frac{\sum (x - M)^2}{n \cdot (n - 1)}}$$



damage upon the first leaves immediately after the larvae have hatched out, especially when large deposits of winter eggs are laid. To avoid this damage, control measures must be started as early as possible. Therefore, a pre-determination of the date when hatching will commence may be of vital importance for the timely organisation of a control.

The forecast of the commencement of hatching is also of practical significance if a control is to be carried out against other pests before the spider mites start to hatch. If it is known when the mites will begin to hatch, the sprays can be delayed until a joint control of both pests is possible. This also applies to a mixed infestation by *Br. praetiosa* and *P. pilosus*. According to Unterstenhöfer (1955), the date of the control in this particular case will be determined chiefly by the emergence of *P. pilosus* larvae. To avoid early damage being caused by *Br. praetiosa*, the control should nevertheless not be carried out too late, and under certain circumstances it ought to be started shortly before *P. pilosus* starts to hatch out. A pre-determination of the hatching date of *P. pilosus* may then contribute towards finding the right date to carry out the control. It was for this reason that I checked whether the method I had developed could also be applied for pre-determining the hatching date of *P. pilosus*.

Method: From February onwards, pieces of branches colonized by eggs were transferred at short intervals from outdoors to the laboratory where they were kept at a temperature of 20°C according to the method described above. A daily check was made to establish when the larvae started to hatch out.

Table 4 gives the results of the tests I conducted.

Table 4: Commencement of hatching (expressed in days) following transfer of the eggs to the laboratory.

| Date when eggs were<br>transferred from outdoors<br>to laboratory | Commencement of hatching<br>expressed in days |      |
|-------------------------------------------------------------------|-----------------------------------------------|------|
|                                                                   | 1954                                          | 1955 |
| February 11                                                       | 8                                             | 13   |
| February 19                                                       | 7                                             | 12   |
| February 28                                                       | 6.5                                           | 10   |
| March 8                                                           | 6                                             | 9    |
| March 25                                                          | 4                                             | 7    |
| April 5                                                           | 2.5                                           | 6    |
| April 12                                                          | 2                                             | —    |
| April 14                                                          | 1.5                                           | 4    |
| April 16                                                          | 1                                             | 3    |
| April 17                                                          | 0.5                                           | —    |
| April 23                                                          | —                                             | 1.5  |
| April 26                                                          | —                                             | 0.5  |

As expected, the larvae emerged earlier in the laboratory at a temperature of 20°C than at the lower temperatures prevailing in the field. The intervals elapsing between the transfer of the eggs and the commencement of hatching is shortened from February to April. If the larvae do not hatch out from the

winter eggs in the laboratory at a temperature of 20°C until after a period of several days, then the commencement of hatching cannot yet be expected at the low outdoor temperatures. When the larvae hatch out after 12–24 hours under laboratory conditions, the first larvae, even at high temperatures, will not appear outdoors until after 1–2 days. This was the case both in 1954 and 1955. On April 17, 1954, and April 26, 1955, the larvae hatched out in the laboratory after 12 hours, and one day later in the field.

It was merely for technical reasons that I transferred eggs from outdoors to the laboratory as early as February. As the approximate period of the commencement of hatching is known for spider mites — *Br. praetiosa* starts to hatch out in April (Table 2) under the climatic conditions prevailing at the Höfchen Research Station — it is sufficient for making such a pre-determination when the transfer of the eggs is started 1–2 weeks beforehand and then continued at short intervals. As a rule it can be taken that when the larvae start to hatch out in the laboratory at 20°C after 12–24 hours, hatching can be expected to commence outdoors 1–3 days later.

It was established from comparative observations that the commencement of hatching can also be pre-determined in this way for *P. pilosus*.

If there are records available extending over several years in respect of the commencement of hatching in the laboratory at 20°C, then the respective development stage of the eggs can be determined by means of comparison. It was found in 1955 that on the same test dates the larvae in the laboratory always hatched out later than in 1954 (Table 4). In view of this it was to be expected that *Br. praetiosa* would hatch out later in the field in 1955 than in 1954.

### 3. Date of hatching and percentage of hatching

Laboratory tests were conducted to establish whether and what influence such factors as exposure to light, relative humidity and temperature have upon the date and percentage of hatching.

#### a) Relation to exposure to light

Method: Pieces of branches colonized by eggs and treated according to the method described above were kept under an exposure apparatus which was fitted with Osram HNT 200 T fluorescent tubes, and radiated approximately 3000 lux. The temperature was 18–20°C, and the relative humidity 50–60%. The 1167 eggs examined were kept exposed in approximately equal parts for 24 and 12 hours respectively, or on the other hand unexposed. The period of exposure was regulated by covering the eggs with

Table 5: Commencement of hatching in relation to the exposure time.

| Date when eggs were transferred from outdoors to laboratory | Commencement of hatching expressed in days |                      |           |
|-------------------------------------------------------------|--------------------------------------------|----------------------|-----------|
|                                                             | exposed for 24 hours                       | exposed for 12 hours | unexposed |
| February 11, 1954                                           | 8                                          | 9                    | 10        |
| February 19, 1954                                           | 7                                          | —                    | 9         |
| February 28, 1955                                           | 10                                         | 10.5                 | 11        |
| March 3, 1955                                               | 9                                          | —                    | 10        |

small wooden boxes. Comparative measurements showed that the temperature and relative humidity values inside the wooden boxes were approximately equal to the values under the exposure apparatus. The commencement of hatching was established by carrying out two checks daily, and at the end of the hatching process the percentage of hatching was calculated by counting the numbers of larvae which had hatched and those which had not hatched. The tests were carried out with four replications.

The results of 4 tests conducted in 1954 and 1955 are given in Table 5.

The percentage of hatching was  $93.1\% \pm 3.4$  for the eggs exposed for 24 hours,  $95.7\% \pm 3.8$  for the eggs exposed for 12 hours, and  $93.7\% \pm 2.1$  for the unexposed eggs.

The eggs which were exposed for 12 hours began to hatch out most rapidly shortly after the start of exposure. Hatching out was also stimulated outdoors by direct solar radiation.

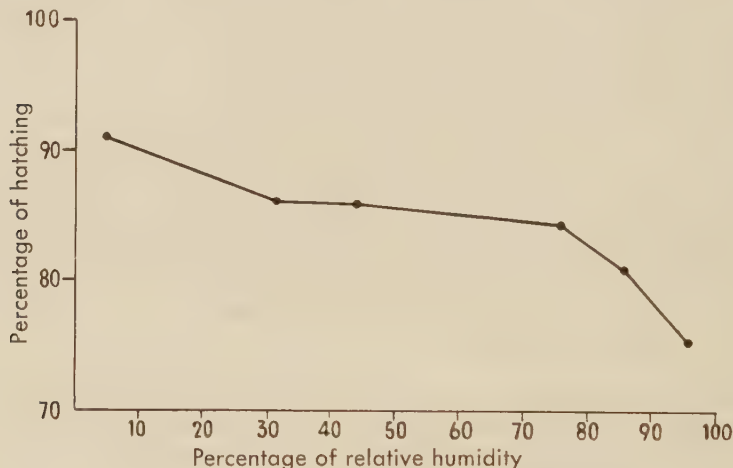


Fig. 7: Percentage of hatching in relation to the relative humidity

Hueck (1951) and Becker (1952) also established that darkness causes a retardation of the commencement of hatching for *P. pilosus*, whereas light has an accelerating effect. They observed, however, that the percentage of hatching for *P. pilosus* was reduced when the eggs were kept unexposed to light.

#### b) Relation to relative humidity

**Method:** Pieces of branches colonized by winter eggs were clamped in glass vessels which were tapered at the bottom. The points where the branches were in contact with the walls of the vessels were surrounded with vaseline to prevent the larvae from migrating. The adjustment of a certain relative humidity was effected by placing salts which could be regarded as being suitable for the biological test (Eichler, 1952), at the bottom of the vessels. Glass plates were fitted to give an air-tight sealing. The bottom surfaces of the plates were coated with grease. The eggs were exposed to light all day long, and kept at a temperature of  $18-20^{\circ}\text{C}$ .

The tests were carried out with 4 replications. A total of 1584 eggs were examined. At first, the commencement of hatching was established by means of daily checks and the number of larvae which hatched out was recorded by taking 2 counts each day. At the end of the hatching process, the percentage of hatching was calculated by counting the number of larvae which did not hatch out.



Fig. 7 illustrates the influence exerted by relative humidity upon the percentage of hatching. When the relative humidity is low, the percentage of hatching is greater than at high degrees of relative humidity. However, there is not a considerable reduction until a value of 80 % relative humidity is exceeded. In contrast, Andersen (1948) found that in the case of *P. pilosus* low relative humidity causes a reduction in the percentage of hatching.

According to the records of the meteorological section at the Höfchen Research Station, the relative humidity from January to April is mostly between 60 and 80 %. In view of this, a reduction of the hatching percentage outdoors is not to be expected.

The commencement of hatching was not influenced by varying degrees of relative humidity.

### c) Relation to temperature

As reported above, the emergence of larvae from winter eggs under field conditions was influenced by the temperature. Laboratory tests were conducted to supplement this result.

**Method:** The pieces of branches colonized by winter eggs and treated according to the method described above, were kept in unexposed stage thermostats or, alternatively, in refrigerators at the required test temperatures. The relative humidity was between 5 and 85 %. It was not expected that the test results would be considerably influenced by this varying degree of relative humidity because the commencement of hatching is not influenced, and moreover the percentage of hatching only fluctuates by 10 % between these values (cf. Fig. 7).

The tests were carried out with 4 replications. A total of 2011 eggs were examined. The date of hatching was established by means of daily checks, and at the end of the hatching process the percentage of hatching was calculated by counting the number of larvae which did not hatch out.

The results of two tests carried out in 1954 and 1955 are given in Table 6.

Considering that spider mites are poikilothermic animals, the close relation between the commencement of hatching and the temperature was to be expected. At low temperatures the commencement of hatching was retarded considerably, although even the lowest temperature examined (5 °C) did not prevent the larvae from emerging. As the temperature increased, there was a very rapid decrease in the time required for hatching, and the time factor reached its lowest value at 33 °C. Further increases of temperature caused an interruption of the hatching process.

The percentage of hatching was reduced by low and very high temperatures. Whereas only 63.1 % of the larvae hatched out at 5 °C, the percentage of hatching was always between 89 and 98 % at temperatures of 19–27 °C. At higher temperatures, the percentage of hatching decreased, and no more larvae emerged at values above 33 °C. The fact that the eggs of *Br. praetiosa* are not killed when exposed to temperatures of 33–40 °C, was proved when eggs which firstly were kept at these values, were subsequently exposed to a temperature of 20 °C, because after a certain time had elapsed the larvae hatched out at this lower temperature (Table 6).

Table 6: Date of hatching and percentage of hatching in relation to temperature.

1st test: March 6, 1954

| Temperature<br>in °C | Rel. humidity<br>in % | Commencement of<br>hatching expressed<br>in days | Percentage of<br>hatching |
|----------------------|-----------------------|--------------------------------------------------|---------------------------|
| 5                    | 75                    | 75 ± 0.8                                         | 63.1 ± 2.1                |
| 8                    | 85                    | 64 ± 0.4                                         | 78.4 ± 1.7                |
| 20                   | 50                    | 6 ± 0.0                                          | 97.7 ± 1.3                |
| 25                   | 45                    | 5 ± 0.0                                          | 90.2 ± 2.9                |
| 30                   | 20                    | 4 ± 0.0                                          | 15.2 ± 4.2                |
| 36                   | 15                    | did not hatch                                    | —                         |
| 40                   | 5                     | did not hatch                                    | —                         |

The eggs kept at temperatures of 36 and 40 °C, together with those eggs kept at a temperature of 30 °C were exposed, at the end of the hatching process of the latter, to a temperature of 20 °C, at a relative humidity of 50 %.

| Previous<br>Temperature<br>in °C | Commencement of<br>hatching expressed<br>in days | Percentage of<br>hatching |
|----------------------------------|--------------------------------------------------|---------------------------|
| 30                               | 6 ± 0.0                                          | 96.1 ± 2.9                |
| 36                               | 8 ± 0.0                                          | 75.4 ± 3.1                |
| 40                               | 8 ± 0.0                                          | 88.7 ± 2.3                |

2nd test: March 5, 1955

| Temperature<br>in °C | Rel. humidity<br>in % | Commencement of<br>hatching expressed<br>in days | Percentage of<br>hatching |
|----------------------|-----------------------|--------------------------------------------------|---------------------------|
| 10                   | 85                    | 41 ± 0.4                                         | 81 ± 2.3                  |
| 19                   | 60                    | 9 ± 0.0                                          | 97.3 ± 1.6                |
| 27                   | 30                    | 5 ± 0.0                                          | 89.2 ± 1.3                |
| 33                   | 15                    | 4 ± 0.0                                          | 18.6 ± 3.2                |

The eggs kept at temperatures of 27 and 33 °C were exposed, at the end of the hatching process, to a temperature of 20 °C, at a relative humidity of 50 %.

| Previous<br>Temperature<br>in °C | Commencement of<br>hatching expressed<br>in days | Percentage of<br>hatching |
|----------------------------------|--------------------------------------------------|---------------------------|
| 27                               | 6 ± 0.0                                          | 91.5 ± 1.2                |
| 33                               | 6 ± 0.0                                          | 82.3 ± 2.9                |

Becker (1952) established in respect of winter eggs of *P. pilosus*, that only one larva emerged at a temperature of 28°C from a total of 78 eggs examined, while at even higher temperatures no larvae hatched out at all. A comparison of these findings with my own observations reveals that the larvae of *P. pilosus* stop hatching out at lower temperatures than those of *Br. praetiosa*.

## B. Development of the Post-embryonic Stages

The purpose of studying the development of the post-embryonic stages was to establish the period of development at different temperatures. Moreover, special attention was given to the influence exerted by moisture upon the development of the post-embryonic stages in order to make sure that a decrease in infestation cannot be caused solely by mechanical washing-off of mites.

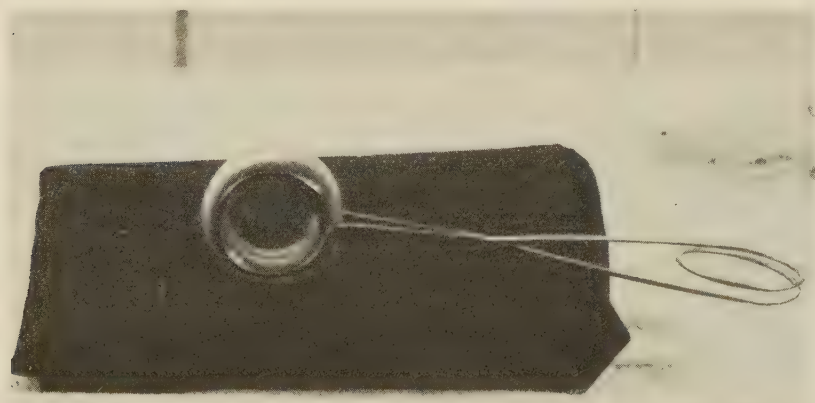


Fig. 8: "Aphid Chamber"

### 1. Influence of temperature

#### a) Period of development of the post-embryonic stages

**Method:** In order to investigate the development period of post-embryonic stages, a method had to be found which would enable mites to be isolated singly. The method Andersen (1948) used for isolating *P. pilosus* on single apple leaves with their stalks surrounded by a vaseline ring, could not be applied because *Br. praetiosa* migrates between the leaves and the branches. On attempting to migrate from the leaves, the mites were caught in the vaseline rings. Also when the isolation was attempted on a leaf and additionally on a part of a branch, the tendency to migrate was so great that the mites became caught in the vaseline.

Isolation was finally effected by means of "aphid chambers" (Fig. 8). Their side walls were made of foam rubber and the tops consisted of a transparent synthetic material which had been rendered permeable to air by making fine punctures in it. These chambers

which could be opened like a pair of tongs, were secured to the leaves (Fig. 9) after the mites which were to be isolated had been placed in the chambers by means of a needle. The leaf served as the base of the chamber, and the isolated mites were able to suck on the upper surface of the leaves.

In field tests, the chambers were secured to leaves of apple seedlings. The apple seedlings were arranged outdoors on a low table, which was surrounded by reinforced muslin in the form of a tent. The table was also used for the purpose of evaluating the test. The entire assembly was covered by glass panes in order to eliminate the interfering effect of rainfall. The mean daily temperatures, as well as the minimum and maximum temperatures were registered by means of a thermograph set up in the field laboratory. The development stage of the mites was established daily under the binocular lens. 12 individual observations were made at the different temperatures.

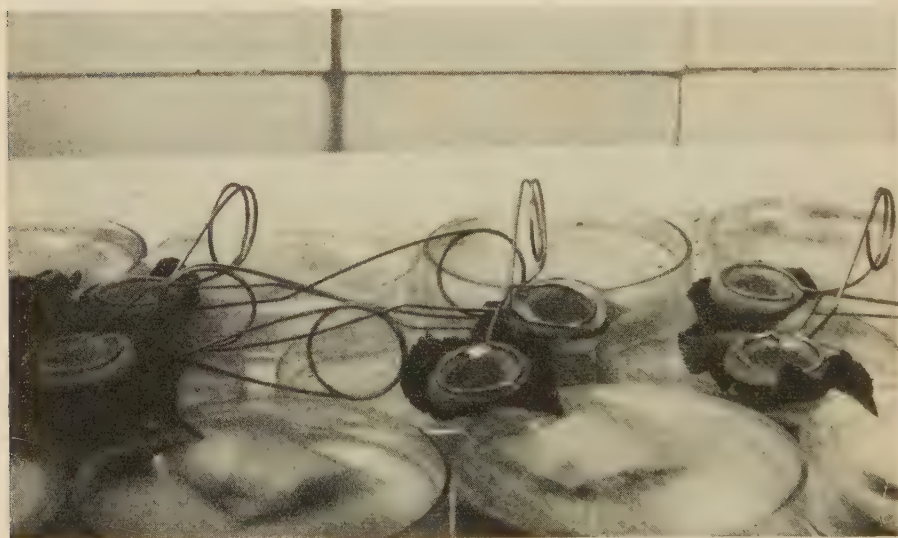


Fig. 9: "Aphid Chambers" secured to leaves

In the laboratory, the mites were isolated with the aid of aphid chambers secured to leaves which had been taken from fruit trees. In order to prevent the leaves from drying up, the leaf stalk was surrounded by cellulose and immersed in Petri dishes filled with water, as illustrated in Fig. 9. However, if a leaf did happen to dry up, it was exchanged for a fresh one. The mites isolated in this manner, were kept in a non-isolated stage thermostat. The evaluation was carried out daily under the binocular lens. 14 individual observations were made daily at the respective temperatures.

This method proved to be most effective not only for studying the development period of the post-embryonic stages but also for carrying out the investigations to establish the length of the pre-ovipositional period and the number of eggs. These investigations will be described later.

Tables 7 and 8 give the results obtained in the field tests, and the results of the laboratory tests are compiled in Table 9.



Table 7: Influence of temperature upon the total period of development up to the occurrence of imagoes (field test).

| Average temperature in °C |             |         | Period of development in days |             |         |
|---------------------------|-------------|---------|-------------------------------|-------------|---------|
| Maximum                   | Daily mean  | Minimum | Maximum                       | Average     | Minimum |
| 15.9                      | 10.7 ± 0.47 | 4.4     | 61                            | 56.7 ± 1.13 | 52      |
| 17.8                      | 14.1 ± 0.56 | 8.1     | 39                            | 36.6 ± 0.87 | 32      |
| 21.1                      | 16.8 ± 0.69 | 12.6    | 27                            | 23.7 ± 0.82 | 20      |
| 23.2                      | 18.8 ± 0.50 | 14.2    | 21                            | 18.3 ± 0.41 | 16      |

Table 8: Influence of temperature on the development period of imagoes (field test).

| Average temperature in °C |             |         | Period of development in days |             |         |
|---------------------------|-------------|---------|-------------------------------|-------------|---------|
| Maximum                   | Daily mean  | Minimum | Maximum                       | Average     | Minimum |
| 14.3                      | 11.3 ± 0.46 | 7.3     | 36                            | 31.2 ± 1.21 | 27      |
| 17.6                      | 14.8 ± 0.24 | 10.1    | 25                            | 20.5 ± 0.84 | 17      |
| 19.9                      | 15.9 ± 0.39 | 11.1    | 22                            | 18.4 ± 0.63 | 14      |
| 24.3                      | 19.2 ± 0.18 | 14.2    | 20                            | 15.2 ± 0.64 | 13      |

Table 9: Influence of temperature on the development period of post-embryonic stages (laboratory test).

| Constant temperature in °C | Larva      | Development period in days |                               |                     |
|----------------------------|------------|----------------------------|-------------------------------|---------------------|
|                            |            | 1st quiescent stage        | Protonymph                    | 2nd quiescent stage |
| 15                         | 5.6 ± 0.22 | 6.4 ± 0.21                 | 5.8 ± 0.24                    | 6.6 ± 0.28          |
| 20                         | 2.6 ± 0.13 | 3.1 ± 0.25                 | 2.5 ± 0.19                    | 2.8 ± 0.24          |
| 25                         | 1.9 ± 0.12 | 2.5 ± 0.17                 | 2.1 ± 0.13                    | 2.4 ± 0.12          |
| 30                         | 1.3 ± 0.07 | 1.7 ± 0.09                 | 1.1 ± 0.07                    | 1.8 ± 0.11          |
| Constant temperature in °C | Deutonymph | Development period in days |                               |                     |
|                            |            | 3rd quiescent stage        | Total development up to imago | Imago               |
| 15                         | 5.3 ± 0.27 | 6.4 ± 0.24                 | 36.1 ± 0.48                   | 23.4 ± 0.73         |
| 20                         | 2.7 ± 0.21 | 3.2 ± 0.19                 | 16.9 ± 0.32                   | 15.9 ± 0.41         |
| 25                         | 2.0 ± 0.14 | 2.6 ± 0.18                 | 13.5 ± 0.31                   | 10.9 ± 0.30         |
| 30                         | 1.4 ± 0.09 | 1.9 ± 0.13                 | 9.2 ± 0.28                    | 7.2 ± 0.27          |

Temperature in °C

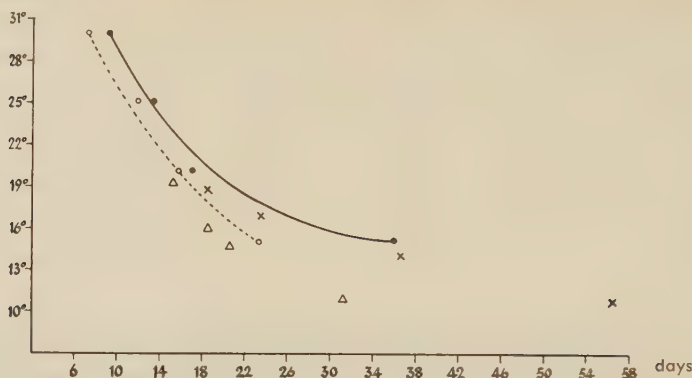


Fig. 10: Influence of temperature upon the development period of the post-embryonic stages

Abscissa: Development period in days

— Total development period up to imago

- - - - - Development period of imago

● Laboratory test (total development up to imago)

× Field test (total development up to imago)

○ Laboratory test (development period of imago)

△ Field test (development period of imago)

The results given in Tables 7—9 are plotted as a graph in Fig. 10.

The numerical values and the course of the curves indicate the great influence which the temperature has upon the development period of the post-embryonic stages, resulting in an acceleration of development at high temperatures and a retardation at low temperatures. The shortest period of development was recorded at a temperature of 30 °C. At a temperature of 35—36 °C, development was disturbed, and the imagoes stopped consuming nutrition. They all died after 60 hours (cf. VII, B. 1. c., Table 12). Accordingly, the shortest period taken by imagoes of *Br. praetiosa* to develop is at a temperature between 30 and 35 °C, referred to by Janisch (1930) as being the most favourable temperature.

Whereas the different quiescent stages, on the one hand, and the larval and nymphal stages, on the other hand, take approximately the same time to develop (Table 9), there is a difference between both groups with respect to their respective periods of development. The quiescent stages develop much more slowly than the larval and nymphal stages.

A comparison drawn between the result I obtained in my studies, and the observations of Linke (1953) and Andersen (1948) shows that *Br. praetiosa* takes approximately twice as long to develop as *Tetr. altheaeae*, and even longer still than *P. pilosus*. This explains why *Br. praetiosa* produces only few generations. A comparison of the outdoor (Tables 7 and 8) and the laboratory values (Table 9) reveals that there is a definite acceleration of development outdoors as compared with the rate of development under conditions in the laboratory.

Stellwaag (1944) drew attention to the contradictory conceptions regarding the comparability of laboratory and outdoor regularities. This applied

particularly to the period of development. Marcus (1934) established that *Panolis flammea* developed much more rapidly outdoors than in the laboratory. The same observation was made by Linke (1953) for *Tetr. althaeae*, and by Stellwaag (1944) in respect of *Clysia ambiguella* and *Polychrosis botrana*.

The reason for this acceleration of development outdoors may be explained by the fact that at the alternating temperatures in the field, the acceleration of development caused by increase of temperature is greater than the retardation of development resulting from a drop of temperature. Moreover, the special conditions prevailing in the laboratory, e. g. absence of light and air movement in stage thermostats, may cause a retardation of development.

#### b) Length of the pre-ovipositional period

The influence exerted by temperature upon the period elapsing between the appearance of imagoes and the beginning of egg-laying, was investigated in laboratory and field tests.

**Method:** Third quiescent stages of *Br. praeiososa* were kept isolated according to the method described above. Daily checks were made to establish when the imagoes emerged from these third quiescent stages. By this means, only freshly emerged imagoes were observed. The start of egg-laying by the imagoes was then established by carrying out daily checks.

The field and laboratory tests were carried out in the outdoor laboratory and in stage thermostats, as described. 12 individual observations were made in the field, and 14 in the laboratory at the respective temperatures.

Table 10 gives the results obtained in the field tests, and those produced by the laboratory tests are compiled in Table 11.

Table 10: Influence of temperature on the length of the pre-ovipositional period (field test).

| Average temperature in °C |             |         | Length of the pre-ovipositional period |            |         |
|---------------------------|-------------|---------|----------------------------------------|------------|---------|
| maximum                   | daily mean  | minimum | maximum                                | average    | minimum |
| 15.4                      | 10.8 ± 0.52 | 6.2     | 7                                      | 5.7 ± 0.36 | 4       |
| 16.7                      | 13.7 ± 0.98 | 7.8     | 6                                      | 4.6 ± 0.29 | 3       |
| 20.2                      | 15.2 ± 1.30 | 12.1    | 5                                      | 3.8 ± 0.22 | 3       |
| 24.6                      | 18.3 ± 1.12 | 13.8    | 3                                      | 2.5 ± 0.12 | 2       |

Table 11: Influence of temperature on the length of the pre-ovipositional period (laboratory test).

| Temperature in °C | Length of the pre-ovipositional period |            |         |
|-------------------|----------------------------------------|------------|---------|
|                   | maximum                                | average    | minimum |
| 15                | 6                                      | 4.2 ± 0.23 | 3       |
| 20                | 3                                      | 2.4 ± 0.11 | 2       |
| 25                | 2                                      | 1.5 ± 0.09 | 1       |
| 30                | 2                                      | 1.1 ± 0.07 | 1       |

The length of the pre-ovipositional period is also greatly influenced by the temperature. High temperatures result in a short period of preoviposition, while at low temperatures the period of pre-oviposition is much longer. In this case, too, it was found that development is much faster under outdoor conditions than in the laboratory.

### c) Effect of extremely high temperatures

Roesler (1954) observed in the Pfalz that infestation by *P. pilosus* on fruit trees collapsed suddenly on hot summer days at a temperature in the shade of 40° C. It therefore appeared interesting to establish at what temperatures the development of *Br. praetiosa* is effected.

The studies were conducted in the laboratory, and at the same time the effect of high temperatures on *P. pilosus* was also tested.

Method: 10 imagoes each of *Br. praetiosa* and *P. pilosus* were narcotized with ether, and placed in an aphid chamber which was clamped tightly to an apple leaf, in the manner described earlier. The mites isolated by this method were then transferred to thermostats in which the temperatures were adjusted as required. As the leaves dried up readily at the high temperatures, they were replaced by fresh ones every day. The test was replicated 4 times at each temperature so that 40 mites were observed each time. The killed mites were counted every 8 hours.

Table 12 gives the results of the investigations.

Table 12: Extermination of *Br. praetiosa* and *P. pilosus* by extremely high temperatures.

| Temperature<br>in ° C | Extermination of imagoes expressed in % after given no. of hrs. |    |    |     |    |     |                   |    |     |     |
|-----------------------|-----------------------------------------------------------------|----|----|-----|----|-----|-------------------|----|-----|-----|
|                       | <i>Br. praetiosa</i>                                            |    |    |     |    |     | <i>P. pilosus</i> |    |     |     |
|                       | 8                                                               | 16 | 24 | 36  | 48 | 60  | 8                 | 16 | 24  | 36  |
| 43—44                 | 0                                                               | 50 | 80 | 100 |    |     | 100               |    |     |     |
| 39—40                 | 0                                                               | 30 | 60 | 100 |    |     | 10                | 80 | 100 |     |
| 35—36                 | 0                                                               | 0  | 0  | 30  | 85 | 100 | 0                 | 30 | 70  | 100 |

Shortly after the test was started, it was observed that at a temperature of 35—36° C the imagoes stopped consuming nutrition, and moved backwards and forwards inside the chambers in a most restless manner. The first dead mites were observed after 36 hours. Development proceeded quite normally at 30° C, as already described earlier. Extermination already began after 16 hours at temperatures of 39—40° C and 43—44° C. After being exposed to these temperatures for 8 hours, the imagoes were so seriously harmed that they were not able to recover at normal temperatures of 15—20° C, and they died shortly afterwards.

In this case too, the values obtained in the laboratory can only be applied with limitations to field conditions because outdoors local climatic conditions are different from those prevailing in the laboratory. Stellwaag (1943) found that on vine leaves outdoors at a temperature of 35.4° C, there was an excess temperature of 5.8° C as compared with the air temperature. The same author also mentions that according to Filzer (1928), the temperatures on leaves of *Polygonum* were in fact 12.3° C higher than in the surrounding air.



No cases of high temperatures having a harmful effect on the imagoes of *Br. praetiosa* were observed outdoors under the climatic conditions prevailing at the Höfchen Research Station. This is quite understandable when it is remembered that the highest temperature recorded outdoors from 1952—1955 was 34° C, in addition to which the temperature only exceeded 30° C on 13 days. Moreover, such high temperatures only prevailed for a short period around midday.

Despite the fact that *Br. praetiosa* is extremely resistant to high temperatures, it always avoids direct solar radiation by seeking protection under the shade of leaves and hiding in bark cracks and depressions in branches. It is quite probable that in this way *Br. praetiosa* escapes the effects of high solar temperatures insofar as they exceed the insect's degree of compatibility with heat.

Table 12 shows that the imagoes of *Br. praetiosa* are more resistant to high temperatures than those of *P. pilosus*. This fact has already been established in respect of the winter eggs of both species. This may well explain why *Br. praetiosa* is the most important spider mite species in such hot countries as South Africa (Massee, 1954), and why it is also an important pest in Australia.

## 2. Influence of Moisture

Epidemiological observations made outdoors revealed that there were large numbers of dead mites on leaves and branches following rainfall. In order to clarify more precisely the influence exerted by moisture on the development of the post-embryonic stages, corresponding laboratory tests were conducted in which *P. pilosus* was again included. It was, however, assumed that the varying degree of compatibility of both species with moisture was the cause for their different rates of occurrence in orchards which vary according to the types of trees grown there and the degree of cultivation.

Method: Leaves colonized by all development stages of *Br. praetiosa* were placed in crystallizing dishes filled with water having a temperature of 18° C. The leaf section not infested by mites lay on the surface of the water. The mite-colonized side was always moist but care was taken that the mites did not submerge under the surface of the water. At the end of the respective treatment periods, the leaves were taken out, and fastened in Erlenmeyer flasks by means of cellulose. A ring of vaseline was placed around the stalk of the leaf to prevent the mites from migrating. It took approximately 4 hours for the leaves to dry out. At the end of this period a count was taken of the living and dead mites.

The results are given in Table 13.

Table 13: Influence of moisture on the extermination of the active stages of *Br. praetiosa* and *P. pilosus*.

| Period during which mite-colonized leaves were placed in water | Extermination of active stages expressed in % |                   |
|----------------------------------------------------------------|-----------------------------------------------|-------------------|
|                                                                | <i>Br. praetiosa</i>                          | <i>P. pilosus</i> |
| 4 hours                                                        | 30                                            | 5                 |
| 8 hours                                                        | 70                                            | 10                |
| 16 hours                                                       | 95                                            | 40                |

The tabulated figures show that a high percentage of *Br. praetiosa* were killed on the moist leaves. When it is considered that the leaves were still moist 4 hours after they had been taken out of the water, then practically all active stages will be killed after they have been on wet leaves for 20 hours. It was only the quiescent stages which survived even the longest period of treatment without suffering any harm. It will be shown later that even outdoors, long periods of rainfall cause a considerable reduction of the infestation of *Br. praetiosa* although the population does not collapse completely due to the survival of the quiescent stages. *Br. praetiosa* is able to avoid exposure to short periods of rainfall by seeking protection on the lower surface of the leaves or in bark cracks and depressions in branches.

Table 13 also reveals that *P. pilosus* tolerates wet conditions on leaves much better than *Br. praetiosa*, which explains, as mentioned earlier, the difference in the degree of occurrence of both species in orchards which vary according to the type of trees grown there and the degree of cultivation.

### C. Summer oviposition

In view of the fact that there are no morphological differences between winter and summer eggs, a check must be made as to when the larvae hatch out of the eggs in order to differentiate between them. The summer eggs hatch out in the same year that they are laid whereas the winter eggs hatch out in the following spring.

Table 14 shows when oviposition commences for the imagoes of the different generations.

Table 14: Commencement of oviposition for imagoes of 1st—3rd generation.

|                | Commencement of oviposition |       |
|----------------|-----------------------------|-------|
|                | 1954                        | 1955  |
| 1st generation | 18.5.                       | 29.5. |
| 2nd generation | 12.7.                       | 11.7. |
| 3rd generation | 27.8.                       | 23.8. |

Three generations were observed at the Höfchen Research Station in 1954 and 1955, and it was found that the imagoes of the 1st generation only laid summer eggs whereas those of the 2nd generation laid winter and summer eggs. The 3rd generation only laid winter eggs.

#### 1. Location of oviposition

In contrast to *P. pilosus* and *Tetr. althaeae* which lay their summer eggs only on leaves, *Br. praetiosa* lays them on both leaves and branches.

In 1954 and 1955, the numbers of eggs laid on branches and leaves of 6 shoot tips were counted at intervals of 6—10 days. Fig. 11 shows the percentages of eggs laid on leaves and branches.

In contrast to the observation made in 1955, it was found that in 1954 most of the eggs of the 1st generation were laid on branches. At the start of

egg-laying by the second generation the percentage of eggs laid on leaves increased in 1954 whilst in 1955 this percentage had already decreased. As the third generation only lays winter eggs, the percentage of egg-laying on the leaves decreased as expected in the late summer of both years.

It was not definitely established whether certain factors have any influence upon the location of oviposition. Since the weather and feeding conditions determine on which parts of the fruit tree the spider mites occur, it is conceivable that the same factors also determine where the summer eggs are laid.

On the leaves, the summer eggs were laid chiefly on the lower surface along the leaf veins and close to the leaf stalk. In fact eggs were even found on the leaf stalk itself. The few eggs laid on the upper surface of the leaf were found in the depressions of the centre vein.

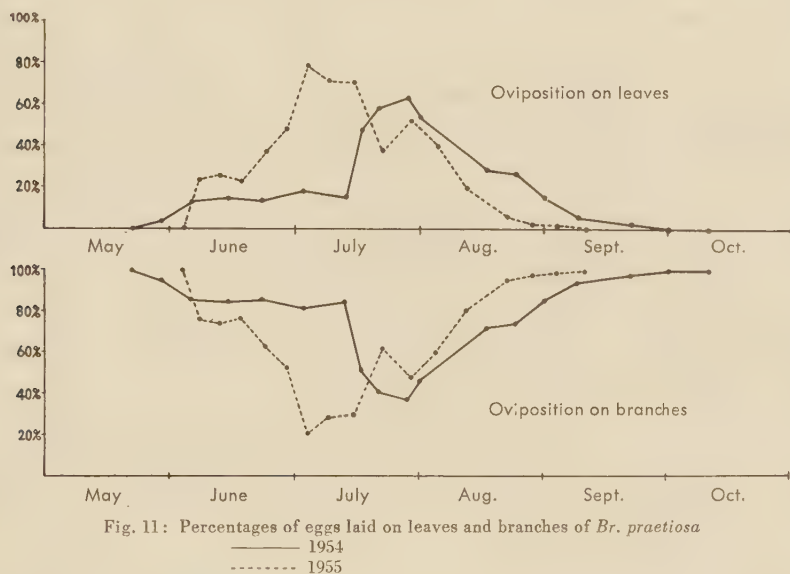


Fig. 11: Percentages of eggs laid on leaves and branches of *Br. praetiosa*  
 — 1954  
 - - - 1955

Egg-laying on branches took place at protected parts in bark cracks and in depressions on the lower surface of the branch. Preference was also shown for those parts of branches growing close to the leaves. Here, eggs are to be found lying next to each other in large numbers in protected places whereas only odd eggs are to be found some distance away from the leaves.

## 2. Number of eggs

**Method:** The isolation of single, freshly emerged imagoes was carried out on apple seedlings in the field laboratory, making use of the aphid chambers described earlier. As the imagoes emerge from the quiescent stages over a long period outdoors, the mites were isolated on different days also in the test. They laid their eggs on the leaves and on the side walls of the aphid chambers because they were not able to migrate to the branches.

After the imagoes had died, the eggs were counted under the binocular lens. The numbers of eggs laid by 12 imagoes were counted for each generation.

Table 15 gives the numbers of eggs laid by the first and second generations. When studying these figures allowance should be made for the fact that the number of eggs laid by the second generation includes winter and summer eggs because no distinction can be made between these morphologically, as mentioned earlier.

Table 15: Number of eggs laid by imagoes of the first and second generations.

|      | Number of eggs laid by imagoes of |             |         |                |             |         |
|------|-----------------------------------|-------------|---------|----------------|-------------|---------|
|      | 1st generation                    |             |         | 2nd generation |             |         |
|      | maximum                           | average     | minimum | maximum        | average     | minimum |
| 1954 | 33                                | 21.9 ± 1.91 | 10      | 23             | 15.7 ± 1.55 | 6       |
| 1955 | 31                                | 20.8 ± 1.63 | 9       | 25             | 17.3 ± 1.41 | 9       |

The above figures show that the imagoes of the first generation laid a greater number of eggs than those of the second generation which, in turn, laid more than the third generation. This decrease in the number of eggs laid from generation to generation was also observed by Andersen (1948) for *P. pilosus*. Newcomer and Yothers (1929) believe that the cause of this is due to an influence being exerted on egg-laying by changes in the nutrient substrate of the leaves as they become older. According to Andersen (1948), however, other unknown factors must exert an influence because he used young shoots for isolating the mites of all generations.

A comparison of the figures obtained in both years does not reveal any significant differences. It should, however, be borne in mind that oviposition in the field laboratory was not influenced by rainfall whereas on the fruit tree rainfall causes the early death of the imagoes and may also greatly affect the number of eggs laid by the different generations from year to year.

According to Andersen an average of 19 eggs are laid by the first to the third generation of *P. pilosus*. Linke (1953) established that all the generations of *Tetr. althaeae* lay 94 eggs on the average. From these figures it is obvious that *Tetr. althaeae* lays far more eggs than *Br. praetiosa* whilst *P. pilosus* lays approximately the same number.

In contrast to *P. pilosus* and *Tetr. althaeae*, only females emerge from the eggs of *Br. praetiosa*, and therefore the number of eggs laid only permits limited conclusions to be drawn regarding the varying development potential of the three species. This question will be dealt with separately at a later stage.

### 3. Duration of embryonic development

The influence exerted by the temperature on the duration of embryonic development was investigated in the field and in the laboratory. The studies were restricted to the first generation because this is the only one which exclusively lays summer eggs.

**Method:** In the field tests, 10 imagoes were placed in each aphid chamber. The chambers were secured to the leaves of apple seedlings set up in the field laboratory. The imagoes were removed from the chambers after a period of 24 hours, and the eggs they had laid were recorded in a sketch. In this way only eggs which had been freshly laid within a period of 24 hours, were observed. A daily check was carried out by means of the binocular lens to establish when the larvae emerged from the eggs.



Batches of 10 imagoes were kept for a period of one day in the aphid chambers in the laboratory tests, too. The chambers were secured to apple leaves. After the chambers had been removed and the eggs had been registered, the latter were placed in an unexposed stage thermostat. Once again daily checks were carried out to establish when the larvae started to hatch out of the summer eggs.

The results are compiled in Tables 16 and 17, and are also plotted as a graph in Fig. 12.

Table 16: Influence of temperature on duration of embryonic development (field test).

| Average temperature<br>in °C |             |         | Duration of development<br>in days |             |         | Number<br>of eggs<br>exa-<br>mined |
|------------------------------|-------------|---------|------------------------------------|-------------|---------|------------------------------------|
| maximum                      | daily mean  | minimum | maximum                            | average     | minimum |                                    |
| 17.3                         | 13.2 ± 0.56 | 8.8     | 33                                 | 30.4 ± 0.38 | 28      | 21                                 |
| 17.9                         | 15.1 ± 0.47 | 10.2    | 26                                 | 24.3 ± 0.24 | 22      | 32                                 |
| 19.5                         | 16.2 ± 0.76 | 10.7    | 23                                 | 21.0 ± 0.23 | 19      | 24                                 |
| 23.8                         | 18.7 ± 0.37 | 14.7    | 20                                 | 18.6 ± 0.12 | 18      | 26                                 |

Table 17: Influence of temperature on duration of embryonic development (laboratory test).

| Constant temperature<br>in °C | Duration of development<br>in days |             |         | Number<br>of eggs<br>examined |
|-------------------------------|------------------------------------|-------------|---------|-------------------------------|
|                               | maximum                            | average     | minimum |                               |
| 15                            | 27                                 | 25.2 ± 0.19 | 22      | 29                            |
| 20                            | 19                                 | 17.6 ± 0.14 | 16      | 25                            |
| 25                            | 12                                 | 11.4 ± 0.09 | 10      | 22                            |
| 30                            | 8                                  | 7.9 ± 0.07  | 7       | 20                            |

Temperature in °C

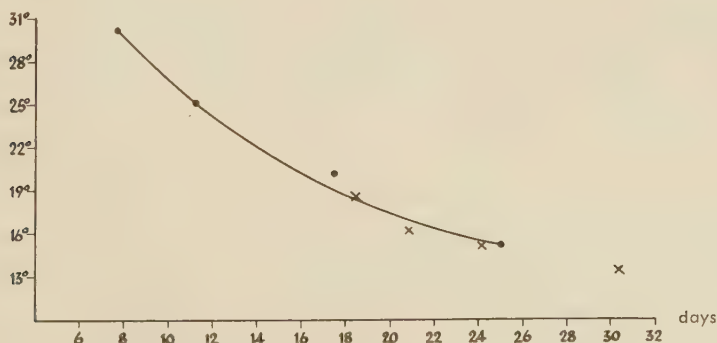


Fig. 12: Influence of temperature upon duration of embryonic development

Abscissa: Duration of development in days

● Laboratory test

× Field test

The values obtained in the laboratory for the duration of the embryonic development correspond approximately, in contrast to the results obtained in the investigations on the duration of post-embryonic development, with the results obtained in the field laboratory. The reason for this conformity may be that the laboratory conditions, e.g. the absence of light and movement of air in the stage thermostat, have less influence upon the embryonic development than upon the post-embryonic development.

The course of the curve (Fig. 12) shows in accordance with expectations that high temperatures accelerate development and low temperatures retard it. The curve tends to drop towards a zero point of development, i.e. "a temperature at which it is theoretically feasible to keep the insect in the same stage for an unlimited period" (Bodenheimer 1927). If the period of development is known at two given temperatures, then the zero point of development, according to Bodenheimer (1927), can be determined computationally by means of the formula:

$$c = T - \frac{t_1 (T_1 - T)}{t - t_1}$$

whereby  $c$  is the abbreviation for the zero point of development,  $t$  the abbreviation for the duration of development in days, and  $T$  the abbreviation for the outdoor temperature in °C.

According to this calculation, the zero point for the embryonic development of the summer eggs of *Br. praetiosa* is between 3 and 6° C (taking as a basis the values for the duration of development at 18.7, 15.1 and 13.2° C). Such low temperatures were recorded on several days at the Höfchen Research Station shortly after the start of summer egg-laying outdoors but only for a few hours during the night. Therefore, it is not to be expected under the climatic conditions prevailing at the Höfchen Research Station, that a considerable influence will be exerted upon the duration of the embryonic development by temperatures which will cause a stoppage in the development of the embryo.

According to Andersen (1948), the embryonic development of *P. pilosus* lasts 10—14 days at an average temperature of 17° C, and 15—21 days at a temperature of 13—14° C. Linke (1953) established that the embryonic development of *Tetr. althaeae* lasts 7.4 days at 18° C, and 15 days at 13° C. This means that the embryonic development of *Br. praetiosa* takes much longer than the other two species. This slow embryonic development, in addition to the duration of the post-embryonic development, is one of the causes why *Br. praetiosa* has a small number of generations.

#### D. Winter oviposition

*Br. praetiosa* overwinters on fruit trees in the egg stage under the climatic conditions prevailing at the Höfchen Research Station. No cases whatsoever were observed of other overwintering stages.

Zacher (1949) reports that *Br. praetiosa* overwinters in the egg stage in the northern parts of the USA whereas in the south all stages were found during the winter. Pritchard and Baker (1952) report that active stages overwinter in the warm parts of California. Both egg and active stages were observed in winter also in the region of Basle (Switzerland) (Grob 1951).

According to Wybou (1951), Roesler (1951), Bauron and Perrot (1953), Tissot and Ferand (1954), only the egg stage overwinters in the countries of Central and Northern Europe. In view of these reports, it must be assumed that all stages overwinter in warm climatic zones with mild winters, whereas only the egg stage overwinters in the conditions prevailing in Central and Northern Europe. The above-mentioned observations were made on fruit trees. All stages overwinter on ivy also under the climatic conditions prevailing at the Höfchen Research Station (cf. VIII. C.).

Winter eggs were laid only by the imagoes of the second and third generations at the Höfchen Research Station in 1954 and 1955. In 1954 egg-laying began on July 12th and in 1955 on July 11th (Table 14) after the end of the pre-ovipositional period of the imagoes of the second generation. Oviposition ended with the death of the imagoes of the third generation in autumn. In 1943 and 1944, Andersen (1948) observed the first winter eggs of *P. pilosus* between the middle and the end of August at the Höfchen Research Station.

An observation which will be discussed at a later stage, gives rise to the assumption that a deterioration of the feeding conditions, in addition to other factors, also has an influence upon the laying of winter eggs. A similar influence exerted upon winter oviposition by the nutrition was also established experimentally in respect of *P. pilosus*, as reported by Roesler (1955). He also mentions that the decrease in the number of hours of daylight is a further factor governing the laying of winter eggs.

#### 1. Location of oviposition

The winter eggs of *Br. praetiosa* are laid only on the branches, chiefly on the lower surface. Preference is shown for 2-year-old and older shoots which because of their rough surface condition provide the mites with the possibility of laying their eggs in protected places, in bark cracks and depressions in branches. The eggs are to be found next to one other in large numbers at such protected places. Together with empty egg and larval skins from the preceding vegetation periods, they form a whitish-red covering on the lower surface of the branches when there is a high rate of infestation.

In order to establish whether preference is shown for one particular side of the tree to lay the eggs, branch specimens were taken from 12 trees of 4 orchards, and the eggs were counted on each metre of 2-year-old shoot. The results are given in Table 18.

Table 18: Oviposition on different sides of fruit trees.

|            | Average number of eggs on<br>1 metre of 2-year-old shoot |
|------------|----------------------------------------------------------|
| East side  | 515                                                      |
| South side | 510                                                      |
| West side  | 353                                                      |
| North side | 129                                                      |
| Tree top   | 190                                                      |

The largest number of eggs were found on the East and South sides of the trees whereas the weakest infestation was on the tree top and the North side.

## 2. Number of eggs

The number of winter and summer eggs laid by imagoes of the second generation have already been given in Table 15, and therefore the following observations will be concerned solely with oviposition of the third generation, in other words exclusively winter egg-laying.

**Method:** The same method was applied as that used in the observations carried out to determine the number of eggs laid by the imagoes of the first and second generations.

Table 19 gives the number of eggs laid by the imagoes of the third generation.

Table 19: Number of eggs laid by imagoes of the third generation.

|      | Number of eggs laid by imagoes<br>of the third generation |                 |         |
|------|-----------------------------------------------------------|-----------------|---------|
|      | maximum                                                   | average         | minimum |
| 1954 | 15                                                        | $10.2 \pm 0.97$ | 5       |
| 1955 | 17                                                        | $11.4 \pm 1.25$ | 6       |

As already mentioned, the above figures show that the number of eggs laid decreases from the first to the third generation, and that the imagoes of the third generation, just like those of the first and second generations, laid approximately the same number of eggs in both test years.

## E. Behaviour of mites on the plants

After hatching out of the winter eggs, the larvae of *Br. praetiosa* immediately migrate to the buds and young leaves of fruit trees in search of food, and like the subsequent stages of development they are to be found chiefly on the upper surface of the leaves. Whereas the entire development of the post-embryonic stages of *P. pilosus* and *Tetr. althaeae* takes place on the leaves, in particular on the lower surface, the active stages of *Br. praetiosa* migrate from the leaves back to the branches where they remain concealed in bark cracks and depressions in the branches. After a certain time they return to the leaves to recommence their feeding activities. Even the ecdysis of the quiescent stages sometimes takes place on the branches (Table 20). In the event of serious infestation, the quiescent stages are to be found crowded together on the lower surface of the branches, particularly during the first generation. On the leaves, the quiescent stages are to be found chiefly in the depression of the midrib on the upper surface of the leaves and along the veins on the lower surface.

Roesler (1952) observed that there is a great tendency for the insects to return to the places where they hatched out of the eggs. In order to infect



potted apple bushes, he secured by means of a pin pieces of bark colonized with winter eggs to the plant. Although the pieces of bark were very parched and in certain cases were almost detached from the plant, some of the larvae migrated to them to moult.

In 1954 and 1955 the active stages and the quiescent stages were counted at weekly intervals on the leaves and the woody parts of 6 shoot tips. The result of the counts are given in Table 20.

Table 20: Different stages of *Br. praetiosa* counted in 1954 and 1955 on the leaves and the woody parts of 6 shoot tips, expressed in percentages.

|                | Larval and nymphal<br>stages on |          | Quiescent stages<br>on |          | Imagoes<br>on |          |
|----------------|---------------------------------|----------|------------------------|----------|---------------|----------|
|                | leaves                          | branches | leaves                 | branches | leaves        | branches |
| 1954           |                                 |          |                        |          |               |          |
| 1st generation | 48 %                            | 52 %     | 8 %                    | 92 %     | 54 %          | 46 %     |
| 2nd generation | 92 %                            | 8 %      | 89 %                   | 11 %     | 58 %          | 42 %     |
| 3rd generation | 99 %                            | 1 %      | 97 %                   | 3 %      | 62 %          | 38 %     |
| 1955           |                                 |          |                        |          |               |          |
| 1st generation | 56 %                            | 44 %     | 12 %                   | 88 %     | 61 %          | 39 %     |
| 2nd generation | 86 %                            | 14 %     | 72 %                   | 28 %     | 51 %          | 49 %     |
| 3rd generation | 98 %                            | 2 %      | 94 %                   | 6 %      | 57 %          | 43 %     |

It is evident from Table 20 that in both test years the number of nymph and quiescent stages on the leaves increases from generation to generation during the course of the year. It would be conceivable for the feeding conditions to become worse from spring to autumn due to the metabolic processes of the tree and also due to the increasing damage caused to the leaves by the mites. This deterioration of the feeding conditions could force the pest to remain longer on leaves serving as sources of nutrition, as the season goes on. The larval, nymphal and quiescent stages in the process of development are particularly affected by this lack of nutrition, and it is for this reason that they are found in increasing numbers on the leaves. As the imagoes lay their winter eggs on the woody parts, they are forced to migrate more frequently from the leaves to the branches. Consequently a large number of them are to be found on the branches also in late summer.

It has been proved in respect of *P. pilosus* what effects serious injuries to the leaves have upon the pest itself. While carrying out plot tests with different sprays, it has been repeatedly observed that in late summer and in autumn the rate of infestation in the check plots is frequently lower than in the adjoining treated plots because when there was a heavy infestation in spring the check trees were so seriously damaged that the mites were not able to find sufficient nutrition in late summer and autumn. Consequently the population collapses for lack of food. Some of the mites, however, are carried by the wind from the damaged control trees to the trees which have been treated in spring and which consequently are less damaged. Here, the mites find better feeding conditions so that a high rate of reproduction may take place in late summer or autumn.

Summers and Baker (1952) also found that there is a relation between the temperature and the sites frequented by the mites. It was observed that during the day at temperatures of 70—85° F (21.2—29.4° C) the mites remained chiefly on the leaves of almond trees (in California). At temperatures of 80—85° F (26.7—29.4° C), they migrated to shaded leaves whilst at night-time and at temperatures of below 60° F (15.6° C) and above 95° F (35° C) their incidence on the branches increased.

I also observed that the temperatures have a certain temporary influence on the sites frequented by the mites. The imagoes, in particular, migrate to shaded leaves at high temperatures, and also seek protection in bark cracks and depressions in branches. It has however already been mentioned that despite these observations *Br. praetiosa* is a species which tolerates heat.

Rainfall may also have an influence on the sites frequented by the mites. If the leaves and branches are wet the mites are not able to change their location. It has been observed that when rain starts to fall the insects withdraw to the lower surface of the leaves and take cover from the rain on the branches.

If the two weather factors, temperature and rainfall, have a great bearing upon the sites frequented by the mites, considerable differences among these sites ought to be established during the two test years. As Table 22 indicates, 1954 was a year with an extremely high rate of rainfall and low temperatures during the summer months whereas in 1955 there was little rainfall accompanied by high temperatures. Nevertheless, the percentages of mites which were found on leaves and branches were approximately the same for 1954 and 1955 (Table 20). Therefore, the sites frequented by the mites were apparently influenced first and foremost by the varying feeding conditions during the vegetation period. In addition temperature and rainfall may be of temporary significance.

## VIII. Epidemiology

The studies on epidemiology deal with the development potential, the population and dynamic factors and the characteristics of the change in population density of *Br. praetiosa* in comparison with other spider mite species. In addition, I have also studied the occurrence and the importance of plant hosts having epidemiologic significance.

### A. Number and temporal occurrence of generations

In addition to the percentage of females and the average number of eggs laid, the number of generations occurring during a vegetation period is also of importance for the development potential of a pest.

Depending upon the environmental conditions, several generations of *Br. praetiosa* occur on fruit trees. Consequently *Br. praetiosa* is to be regarded as a polyvoltine species on the fruit trees whereas on gooseberries it is a univoltine species because only one generation occurs on this particular host. As a varying number of generations occur on other groups of plant hosts (Table 24), the host plant must always be given, to which the observations apply.

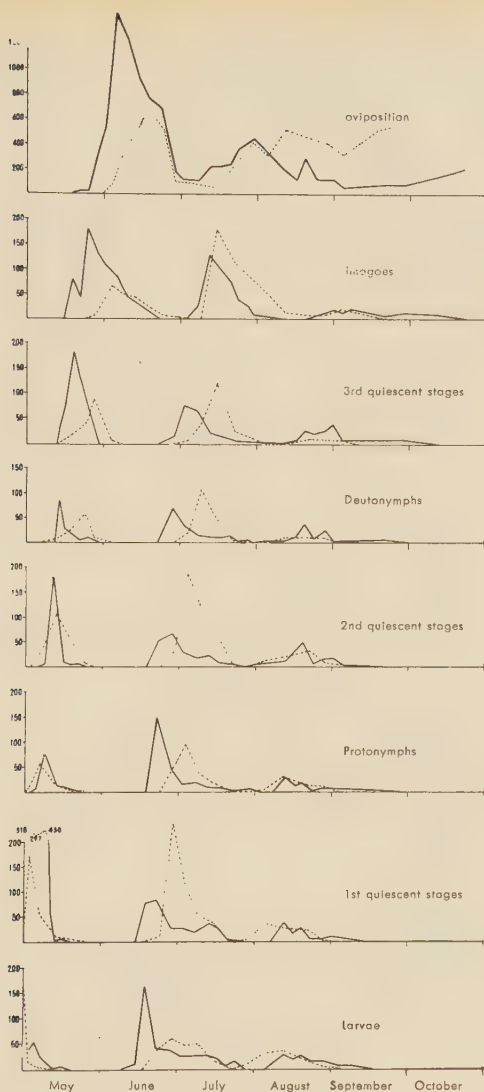


Fig. 13: Temporal occurrence of the development stages by *Br. praetiosa*, and their infestation density on 6 shoot tips during 1954 and 1955

Ordinate: Number of development stages found on 6 shoot tips  
 — 1954                      - - - - - 1955

Considering that my studies deal chiefly with the form of *Br. praetiosa* occurring on deciduous fruit, I have only mentioned the numbers of generations which in the literature have definitely been observed on fruit trees. Fjeldalen (1952) and Wybou (1951) found three generations of *Br. prae-*

*tiosa* in Norway and Belgium respectively. Roesler (1952) observed four generations in the Pfalz, and the same number was established by Bauron and Perrot (1953) in the vicinity of Paris, and by Tissot and Ferand (1954) in the district of Lyons. Lounsbury (1903) quotes a minimum of four generations for Cape Province, whereas Mathys (1953) refers to the occurrence of 7—8 generations in the district around Lausanne. Even though 7—8 generations may appear to be somewhat high — Mathys mentions that *P. pilosus* only has 6—8 generations in the same district — it is, however, quite likely that more than 4 generations occur in warm regions when there is a definite relation between the number of generations and the climatic conditions.

The number and the temporal occurrence of generations were observed in 1954 and 1955 at the Höfchen Research Station.

**Method:** The numbers of the different stages of development were counted on 6 shoot tips at intervals of 5—10 days (Fig. 13). The evaluation was carried out at shorter intervals, namely when the commencement of egg-laying by the imagoes and the death of the last imagoes of a generation were to be expected, because these dates are very important for making an exact temporal separation of the generations. In this way it was possible to make an exact temporal separation of up to three generations (Fig. 13), and therefore it was not necessary to isolate the different generations by making transfers to non-infested pieces of branches as Andersen (1948) did when he conducted his studies on *P. pilosus*.

The period of the first generation extends from the time when the larvae begin to hatch out of the winter eggs until the death of the imagoes of this generation, while the period of the other generations lasts from the commencement of egg-laying by the imagoes of the preceding generation until the death of the imagoes emerging from these eggs.

Whereas Fig. 13 shows the occurrence of the different stages within the generations, Fig. 14 gives a summarized illustration of the number and the temporal occurrence of the generations in 1954 and 1955. Table 21 augments the illustrations by giving details on the period of the different generations and the mean daily temperatures recorded during these periods.

Table 21: Temporal occurrence of generations in 1954 and 1955.

|                |                  | Mean daily temperature<br>expressed in °C |
|----------------|------------------|-------------------------------------------|
| 1954           |                  |                                           |
| 1st generation | Apr. 18—June 22  | 13.5                                      |
| 2nd generation | May 18—Aug. 12   | 15.6                                      |
| 3rd generation | July 12—Oct. 22  | 14.8                                      |
| 1955           |                  |                                           |
| 1st generation | Apr. 27—June 28  | 12.7                                      |
| 2nd generation | May 29—Aug. 18   | 16.8                                      |
| 3rd generation | July 11—Sept. 22 | 17.2                                      |



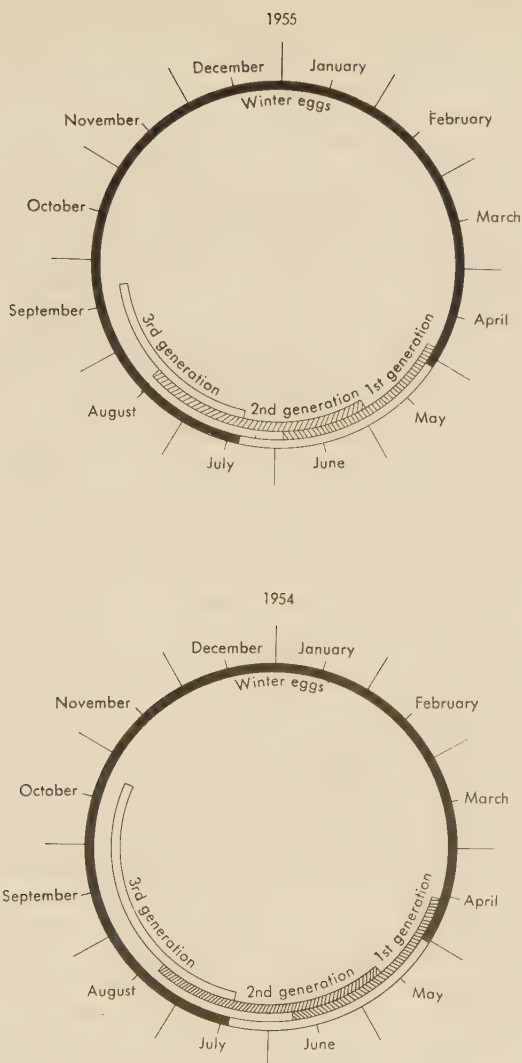


Fig. 14: Temporal occurrence of generations in 1954 and 1955

Three factors have been found to exert a considerable influence upon the number and the temporal occurrence of generations: 1. The commencement of hatching-out of the larvae from the winter eggs (commencement of the first generation). 2. The weather conditions, particularly the level of the temperatures during the vegetation period. 3. The feeding conditions.

In 1955, the larvae of *Br. praetiosa* hatched out of the winter eggs 9 days later than in 1954 and even 19 days later than in 1953 (cf. Table 2). As the

mites of the first generation start to develop at the same time as the commencement of hatching takes place, this delay in the temporal occurrence of the first generation, namely when there is a repetition of late commencement of hatching by the subsequent generations, may result in a low number of generations or an incomplete development of the last generations.

It has already been mentioned that in Europe the number of generations increases from north to south depending upon the climatic conditions. It is a known fact, and has already been proved with respect to *Br. praetiosa* that high temperatures cause an acceleration of development, and low temperatures a retardation. The relation between the speed of development of the different stages and the temperature naturally has an overall effect upon the number of generations produced and their temporal occurrence. Table 21 and Fig. 14 illustrate that despite the late commencement of hatching in 1955, the third generation occurred one day earlier than in 1954 due to the prevailing weather conditions which at the time favoured the development of spider mites, in particular the high temperatures. Other consequences of the high temperatures prevailing during the occurrence of the third generation was that the development of this generation already came to an end on September 22. I shall mention later why a fourth generation was not produced despite the early completion of the development of the third generation.

The nutrition factor may also influence the number of generations produced. According to Roesler (1955), it has been established experimentally with respect to *P. pilosus* that the production of winter eggs may be caused both by the daily exposure to light as well as by the deterioration of the feeding conditions. Gasser (1951) established a relation between the occurrence of winter females of *Tetr. althaeae* and leaf metabolism. It has already been mentioned that the feeding conditions probably influence the sites frequented by the post-embryonic stages of *Br. praetiosa*. Moreover, they apparently exert an influence upon winter oviposition. Although the last imagoes of the third generation were observed on September 22 in 1955, namely one month earlier than in the previous year, a fourth generation was not produced despite favourable weather conditions because the imagoes had only laid winter eggs. The tree under observation had not been treated with chemical preparations, and therefore it was seriously harmed by mites and diseases. The imagoes of the third generation had also laid summer eggs on trees which had suffered less damage, and larvae emerged from these eggs. The early laying of winter eggs apparently caused by lack of food, may therefore limit the number of generations produced. On the other hand I had only found winter eggs on the observed tree from October 22 onwards because at this time the tree had already shed all its leaves. On other trees which retained their foliage for a longer period, mites were found until November 1st, yet a fourth generation was not produced.

*Br. praetiosa* undoubtedly produces fewer generations per year than *P. pilosus* and *Tetr. althaeae*. Lienk and Chapman (1951) observed 8 generations of the two latter species and only 5 generations of *Br. praetiosa* in the vicinity of New York. Excellent possibilities for drawing comparisons are offered by the papers of Andersen (1948) and Linke (1953) who, like myself, conducted their studies at the Höfchen Research Station. Andersen (1948) found that *P. pilosus* produced 5 generations both in 1943 and 1944.

Linke (1953) observed 6 generations of *Tetr. althaeae* in 1951, and he is of the opinion that under favourable weather conditions 7—9 generations may be produced.

## B. Change in population density

A condition for the development of an epidemic is the mass reproduction of the causal organism. Since each species is capable of mass reproduction, it depends merely upon the ecological delimitation factors whether an epidemic will break out. I examined the temperature and moisture as the most important abiotic factors and the predators as the biotic factor.

### 1. Weather and change in population density

**Method:** All stages occurring on the leaves and branches of 6 shoot tips were counted at intervals of 5—10 days from the time the larvae started to hatch out of the winter eggs in spring until the death of the last mites in autumn. The shoot tips were taken from different sides of a tree on which no cultivation or control measures had been carried out.

Fig. 13 illustrates the infestation on 6 shoot tips undivided according to the different stages of development. Figs. 15 and 16 give the total infestation of all post-embryonic stages, and the mean daily temperatures and amounts of rainfall recorded during the period of observation. Table 22 gives details of the monthly average daily temperatures and the amounts of rainfall from April to October.

Table 22: Mean daily temperatures and amounts of rainfall from April to October in 1954 and 1955 at the Höfchen Research Station.

|           | Mean daily temperature in °C |      |      |      |      |       |      |
|-----------|------------------------------|------|------|------|------|-------|------|
|           | April                        | May  | June | July | Aug. | Sept. |      |
| Average   |                              |      |      |      |      |       |      |
| 1946—1953 | 9.0                          | 13.6 | 16.3 | 17.3 | 16.4 | 13.3  | 9.2  |
| 1954      | 7.6                          | 13.8 | 16.3 | 15.0 | 16.1 | 15.2  | 11.5 |
| 1955      | 8.2                          | 10.0 | 15.2 | 18.1 | 18.0 | 14.0  | 7.8  |

|           | Rainfall in mm |      |      |       |       |       |       |
|-----------|----------------|------|------|-------|-------|-------|-------|
|           | April          | May  | June | July  | Aug.  | Sept. |       |
| Average   |                |      |      |       |       |       |       |
| 1946—1953 | 47.5           | 60.4 | 75.7 | 82.0  | 89.6  | 63.9  | 49.2  |
| 1954      | 40.7           | 84.7 | 99.0 | 165.2 | 125.0 | 90.3  | 125.9 |
| 1955      | 32.1           | 64.2 | 66.2 | 34.5  | 75.5  | 70.8  | 54.1  |

The temperature values and the amounts of rainfall differ considerably in both test years. In fact one can speak of extreme years with respect to the amount and distribution of rainfall. It was therefore to be expected that moisture would have a very great influence on the population density in both test years.

The amount of rainfall may cause a reduction of infestation from three aspects:

1. By killing the active stages on wet leaves. A similar knock-down was observed in laboratory tests, and this was confirmed in the field by the presence of large numbers of dead mites on branches and leaves of fruit trees following rainfall.
2. Due to the mechanical effect of rainfall, mites may be washed off the trees.
3. Wetting of leaves affects the habits of the mites, and leads to retardation of development (Linke 1953).

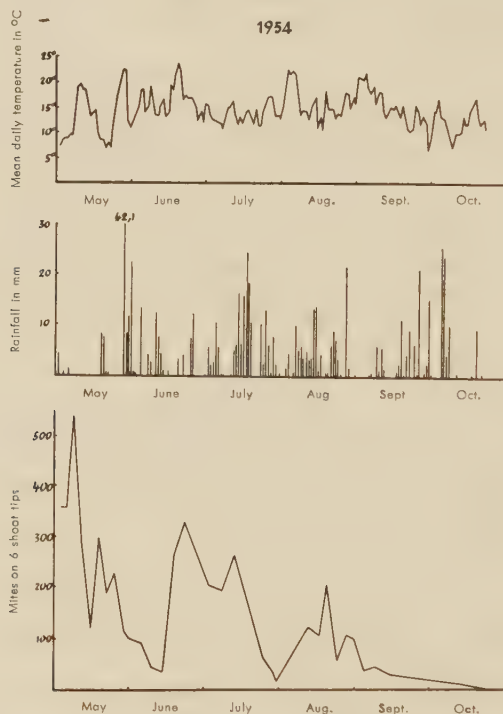


Fig. 15: Infestation by post-embryonic stages of *Br. praetiosa* on 6 shoot tips (1954)

The facts mentioned under 1. and 2. apply only to the active stages because the quiescent stages, as already shown, are not killed by remaining on wet leaves and moreover they are not washed off the trees. Consequently the population density can be reduced by rainfall only when active stages are present on the fruit trees at the time.

The temperature influences the rate at which the embryonic and post-embryonic stages develop, and in consequence of this it may also exert an influence on the number of generations produced. In view of the high degree to which *Br. praetiosa* is compatible with heat, it is not likely that very high temperatures will have a direct influence upon the population density by kill-



ing the mites under the climatic conditions prevailing at the Höfchen Research Station, such as Roesler (1954) observed for *P. pilosus* in the Pfalz at a temperature in the shade of 40° C.

In Figs. 15 and 16, there is a clear distinction between the three generations produced during the test years. A comparison of the illustrations shows that in 1954, due to the high rate of winter oviposition in the preceding year, the degree of infestation was high at the start of the first generation, whereas in 1955 the degree of infestation was low due to the fact that few winter eggs

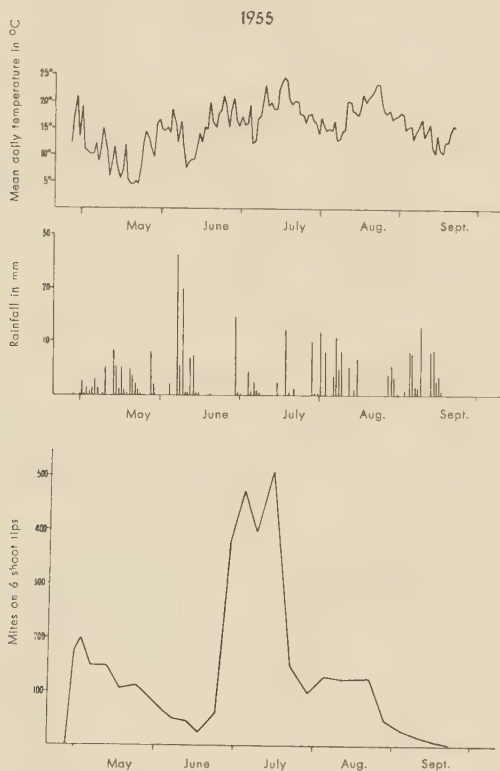


Fig. 16: Infestation by post-embryonic stages of *Br. praetiosa* on 6 shoot tips (1955)

were laid the previous year. In both test years, the population density of the first generation was not greatly influenced at first by rainfall, with the result that a large number of summer eggs were laid. This number was higher in 1954 than in 1955 due to the presence of a greater number of imagoes (Fig. 13). The heavy rainfall at the end of May 1954 and in the middle of June 1955 did not have much effect on the population density because the imagoes had already laid a large number of eggs, and apart from the imagoes there were no other active stages present on the trees.

In view of the number of eggs established, there ought to have been a great population density during the second generation in 1954. However, the infestation decreased considerably because of the unusually heavy rainfall in July and August of this particular year, which caused eradication of the post-embryonic stages. In 1955, on the other hand, the development was not hindered by rainfall so that the rate of infestation increased from the first to the second generation. Consequently the infestation in 1955 was more serious despite the fact that fewer eggs were laid.

In both test years, there was a great reduction in the population density of the third generation, a tendency also observed by Grob (1951) in the Western parts of Switzerland. This drop cannot be attributed solely to weather influences otherwise the varying amounts of rainfall in both test years ought to have resulted in corresponding differences of infestation. The drop in population density during the third generation is also due to a greater occurrence of predators, and moreover due to the laying of winter eggs by imagoes of the second generation. The commencement of winter oviposition and the percentage of winter eggs in relation to the total oviposition are influenced by the feeding conditions. The percentage of winter eggs in relation to the total oviposition of the second generation varied greatly in both years, being low in 1954 and high in 1955. Consequently the population density of the first generation was only slight in Spring, 1955 whereas the relatively high rate of winter oviposition in 1955 provided a basis for a high population density in the following year.

Although the number of winter eggs laid basically determines whether there will be a heavy or slight infestation in the following Spring, the later density of the population is influenced by the weather conditions during this period. Dry and warm weather leads to a high population density whereas wet and cold weather keeps the population density at a low level.

## 2. Occurrence and importance of predators

There are different opinions on the importance of predators as a limiting factor to the change in population density. Geijkes (1938) and Vitzthum (1943) point out that it is necessary to protect beneficial insects but they emphasize that the predators cannot prevent mass reproduction. Andersen (1948) established that beneficial insects, due to their late appearance, cannot prevent the reproduction of *P. pilosus* on their own. Roesler (1954) attaches little importance to the natural enemies, in contrast to the weather. Kemp (1947), Webster (1948), Newton and List (1949), Gallay (1950) and Barnes (1951) observed that the infestation of *Br. praeiosa* increased due to the eradication of predators following spray applications of DDT. Past studies on the occurrence of predators have been centered chiefly on *P. pilosus* and *Tetr. althaeae*. Comprehensive data on this are given in the papers of Newcomer and Yothers (1929), Geijkes (1938), Listo (1939) and Günthart (1945). The question as to whether the known predators of *P. pilosus* and *Tetr. althaeae* may also influence at the same time the mass reproduction of *Br. praeiosa*, can only be answered in respect of a few species on the basis of the available literature and my own observations.

According to Lord (1949) *Haplothrips fauri* Hood destroys the eggs of *Br. praeiosa*. MacPhee (1953) emphasizes that this beneficial insect can cause a big drop in the infestation under favourable conditions due to its development potential. Other thrips which influence a mass reproduction of

# Höfen Research Station

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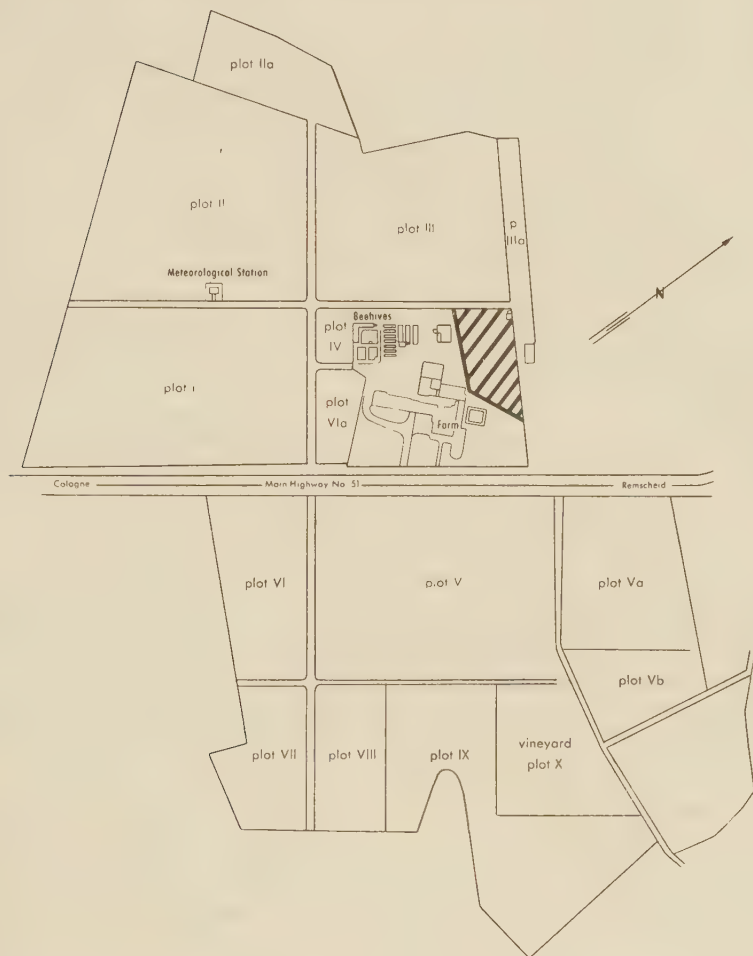


Fig. 17: Plan of the test plots

*Br. praetiosa* are *Leptothrips mali* Filch., *Haplothrips americanus* Hood and *Scolothrips sexmaculatus* Perg., according to Baily (1940) and Lord (1949). The eggs and quiescent stages of *Br. praetiosa* are destroyed by *Conwentzia pineticola* End. (Withcombe 1924). *Anthocoris nemorum* L., one of the order of Anthocorida and also one of the most important enemies of *P. pilosus*, attacks the active stages of *Br. praetiosa* (Wybou 1951). Evans (1942) established that among the order of Coleoptera, *Scammus vagans* Blkb. is a predator of *Br. praetiosa*. The eradication of *Br. praetiosa* by predatory mites is reported by Lord (1949) and Hantsbarger and O'Neill (1954).

In 1954 and 1955, I conducted studies on the occurrence and the importance of predators at the Höfchen Research Station.

The occurrence of predators was studied in combination with the counts taken to determine the change in population density of *Br. praetiosa* (the method applied for taking these counts is described earlier in the paper). In view of the fact that the counts were taken on shoot tips which also had to be transferred from outdoors to the laboratory, a complete quantitative check could only be made of those predators which complete their development on the leaves during the vegetation period and which do not fall off or fly away from the shoot tips while they are being transferred to the laboratory. Consequently the quantitative check was only possible on one predatory mite species whereas the occurrence of other species was observed on the fruit trees themselves without any numerical records being noted.

The location at which the observations were made is shown by means of shading in Fig. 17. The surrounding plots I—X had been treated regularly with different kinds of pesticides for some time past but the trees at the observation site, which were predominantly old stands, had not been treated with chemical preparations as part of control measures for the last 8 years.

In those cases where it could not be definitely stated on the basis of field observations whether the discovered species belonged to the groups of predators of *Br. praetiosa* and which stages they attacked, they were isolated together with the different development stages of *Br. praetiosa* in the aphid chambers described earlier, in order to make a closer study.

The observations revealed that the two Anthocorida, *Orius minutus* L. and *Anthocoris nemorum* L., suck out all stages of *Br. praetiosa* including the eggs. Neither of these two species appeared on the trees until the end of July. *Scymnus punctillum* also eradicated all stages of *Br. praetiosa*. The field observations give rise to the assumption that these three species do not occur in large numbers.

In addition to the above-mentioned enemies, a predatory mite of the *Typhlodromus* genus was also found, although it was not possible to define its species precisely. It only sucked out the eggs of *Br. praetiosa*. This predatory mite appears on the leaves from May onwards, and its imagoes overwinter under the bark of fruit trees. It is to be found on the lower surface of the leaves close to the veins, and produces several generations. The mites begin to migrate to their winter hiding places between the end of September and

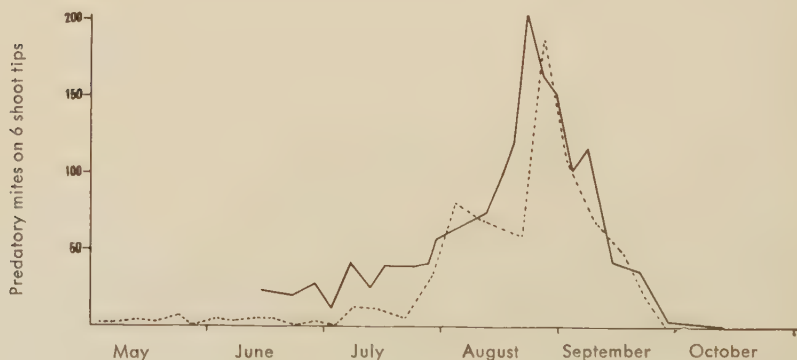


Fig. 18: Occurrence of post-embryonic stages of a predatory mite of *Typhlodromus* genus on leaves of 6 shoot tips  
—— 1954  
----- 1955



the beginning of October, and they suck out any winter eggs which they find on the branches while they are migrating.

Fig. 18 illustrates the occurrence of post-embryonic stages of the above-mentioned *Typhlodromus* species on the leaves of 6 shoot tips in 1954 and 1955.

Very few predatory mites were to be found between May and July but in August their population density increased considerably and reached its climax at the end of this particular month. The predatory beetles did not occur either until the end of July so that the predators were hardly able to influence the degree of infestation of the first and second generations of *Br. praetiosa*. They merely participated in causing a decrease in the population density of the third generation (Figs. 15 and 16) and consequently they also exerted an influence on the number of winter eggs laid. The comparison drawn between the numbers of winter eggs laid in 1954 and 1955 (Fig. 13) shows however that the predatory mites were not able on their own to cause a considerable decrease in the rate of winter oviposition. Although the number of predatory mites established in 1955 was not less than in 1954, and the field observations did not reveal a weaker occurrence of other predators, the number of winter eggs laid in 1955 was considerably higher than in 1954 due to the abiotic factors which exerted their influence at the same time. On the other hand, infestation of *Br. praetiosa* may increase most considerably during the course of the summer provided the weather conditions are favourable, this despite the fact that only relatively few winter eggs may have been laid.

### 3. Characteristics of the change in population density of *Br. praetiosa* compared with other spider mite species

When several spider mite species occur simultaneously in orchards, a knowledge of the characteristics of the change in population density of these species may prove to be of favourable assistance in deciding whether it is possible to carry out a joint control, and if so, contribute towards increasing the economy of plant protection measures. The investigations carried out by Unterstenhöfer (1955) and my own records (cf. Table 1) show that *P. pilosus* and *Br. praetiosa* which under our conditions are the two most important spider mite species, occur together in many orchards. Occasionally other species also occur on a large scale. Grob (1951) mentions *Tetr. althaeae* as an important pest occurring in Switzerland.

Excellent possibilities for comparing the change in the population density of these three species are provided by the papers of Andersen (1948) and Linke (1953) and by my own studies because all these investigations were

Table 23: Development potential of *Br. praetiosa*, *P. pilosus* and *Tetr. althaeae*.

|                              | Percentage of<br>females<br>(sex index)<br>♂♂   ♀♀ | Average number<br>of eggs | Number of<br>generations |
|------------------------------|----------------------------------------------------|---------------------------|--------------------------|
| <i>Br. praetiosa</i>         | 0 : 1                                              | 16.2                      | 3—4                      |
| <i>P. pilosus</i> (Andersen) | 1 : 1                                              | 19                        | 5                        |
|                              |                                                    | (1st—3rd gen.)            |                          |
| <i>T. althaeae</i> (Linke)   | 1 : 2.3                                            | 94                        | 6—9                      |

carried out at the same location and consequently under the same ecological conditions.

*Br. praetiosa*, *P. pilosus* and *Tetr. althaeae* are capable of large-scale mass reproduction due to the difference in their development potential.

*Tetr. althaeae* has the greatest development potential due to its large number of eggs and generations. As Andersen (1948) only gives a precise number of eggs for the first and third generations of *P. pilosus* but mentions a decrease from the first to the fifth generations, it may be assumed that the number of eggs laid by this species is not much higher than the number laid by *Br. praetiosa*. The difference in the development potential of these species is therefore determined by the greater number of generations produced by *P. pilosus* resulting from speedier development, although this is partly offset by the constant thelytoky of *Br. praetiosa*.

The three species also vary during the course of gradation.

Linke (1953) observed that the winter females of *Tetr. althaeae* occur on hops in May, and states that the infestation increased gradually reaching its climax in August and in September. Chapman and Lienk (1950) found that the climax of infestation on fruit trees was also reached in late summer.

Under the climatic conditions prevailing at the Höfchen Research Station, the larvae of *Br. praetiosa* hatch out in April either during or shortly after bud burst, while the larvae of *P. pilosus* emerge approximately 1—2 weeks later. The degree of infestation at the beginning of the first generation is determined by the number of winter eggs for both species. A factor which has a great bearing upon their joint control is that they start to lay their summer eggs at approximately the same time due to the greater speed at which *P. pilosus* develops. The climax of infestation may be reached between the end of the hatching-out process and the commencement of winter oviposition. The degree of infestation decreases as soon as the pests start to lay their winter eggs. *Br. praetiosa* commences laying its winter eggs in July, and according to Andersen (1948) *P. pilosus* starts its winter oviposition in August. As a general rule no further post-embryonic stages of *Br. praetiosa* are to be found on the trees from the middle to the end of October while the same stages of *P. pilosus* disappear in November.

As the damage caused to the first stages by the first generation is of great importance for the vegetative and generative development of fruit trees (Unterstenhöfer 1955), both species, especially *Br. praetiosa*, may be regarded as early pests whereas *Tetr. althaeae* has the character of a late pest.

### C. Plant Hosts as Infectors for the Colonization of Fruit Trees by *Br. praetiosa*

A problem of epidemiological significance is whether other plant hosts colonized by spider mites, in addition to fruit trees, may serve as the starting point for a new infestation. Unterstenhöfer (1955) drew attention for the first time to the great importance of this problem. He frequently observed, following effective control measures, a recolonization of fruit during the course of the vegetation period, which was so extensive that it could not be attributed solely to the reproduction potential of the mites that survived the

controls. During his studies, he found a number of plant hosts which could be regarded as infectors for the colonization of the fruit trees by spider mites.

Andersen (1948) studied the propagation of spider mites by the wind. He trapped 200 to 400 mites per hour over an area of 1 square metre at a distance of 3 metres from the edge of the tree tops, with the wind blowing at a velocity of 3 to 4 metres per second. He mentioned that in view of the light weight of the mites, they might be carried by the wind over long distances.

Unterstenhöfer (1955) emphasizes the necessity of investigating the range of plants hosts with respect to this problem of epidemiological importance, so that if need be, plant hosts acting as infectors can be treated during controls or completely destroyed.

I complied with Unterstenhöfer's (1955) suggestion by investigating the plant hosts to *Br. praetiosa* in the Rhenish-Bergisch district. It could not be assumed from the outset that with respect to *Br. praetiosa*, mites can be transferred from one plant to another. Roesler (1952) failed with his transfer trials from gooseberries to apples and pears, whilst Zacher (1949) and Roosje and van Dinther (1953) were also unsuccessful with their transfer tests from ivy to gooseberries and vice-versa. As the habits of *Br. praetiosa* vary on certain groups of plant hosts (Table 24), it is assumed today that the species defined as *Br. praetiosa* embodies several biological strains (Roesler 1952; Pritchard 1953) or even species (Weidner 1954) especially as Eynhoven (1955) established morphological differences among the mites occurring on various plant hosts.

In view of the fact that systematic studies have not yet established on which specific plant hosts the different strains or species occur, it was only by conducting numerous transfer trials that it could be ascertained which plants are to be considered as infectors from which the fruit trees are attacked by *Br. praetiosa*.

My own studies commenced with an investigation of the development of *Br. praetiosa* on different plant hosts. The result was that five groups of plant hosts were established on which the development of *Br. praetiosa* appeared to correspond. (Reference should be made to Section IV, "Plant Hosts", for details as to which plants belong to these groups because all the hosts could not be included in Table 24.)

The classification of the plant hosts in one of the five groups initially established by studying the development of the mites was then confirmed by

Table 24: Development of *Br. praetiosa* on certain groups of plant hosts.

| Plant host group                      | Overwintering | Commence-<br>ment<br>of hatching | No. of<br>gene-<br>rations | End of in-<br>festation<br>by post-<br>embryonic<br>stage |
|---------------------------------------|---------------|----------------------------------|----------------------------|-----------------------------------------------------------|
| 1. Fruit trees                        | Egg stage     | April                            | 3—4                        | October                                                   |
| 2. <i>Ribes</i> sp.                   | Egg stage     | March                            | 1                          | June                                                      |
| 3. <i>Crataegus</i> sp.               | Egg stage     | April                            | 1                          | June-July                                                 |
| 4. Ivy                                | All stages    | —                                | continuous generations     |                                                           |
| 5. Grasses and her-<br>baceous plants | ?             | ?                                | several                    | ?                                                         |

means of transfer trials. Particular interest was shown in the first group of plant hosts, which in addition to the fruit species also includes buckthorn (*Prunus spinosa* L.) and an ornamental apple (*Malus Scheidekeri* Zabel).

**Method:** Potted apple seedlings were set up in the field laboratory and in the indoor laboratory, their stems coated with a vaseline ring and then infected by suspending on them plant parts taken from other hosts colonized by all stages of *Br. praetiosa*. A weekly check was carried out to determine the development stage of the mites on the new plants, and also to establish whether the mites attempted to migrate. At the same time, mites were also isolated and transferred from certain plant hosts to apple leaves or to leaves of other examined plant hosts, in the aphid chambers.

In view of the abundance of material to be examined, the studies had to be conducted solely on apples using potted plants whereas the transfer to other plant hosts on single leaves had to be carried out by means of the aphid chambers.

The result of the first transfer test which was only carried out on a few fruit varieties, is given in Table 25.

Table 25: Transfer test between different fruit varieties.

| from   | Apple | Pear | Plum | Cherry |
|--------|-------|------|------|--------|
| to     |       |      |      |        |
| Apple  | +     | +    | +    | +      |
| Pear   | +     | +    | +    | +      |
| Plum   | +     | +    | +    | +      |
| Cherry | +     | +    | +    | +      |

+ = Transfer successful, normal development and reproduction.

As expected, the transfer between the different fruit varieties proved to be successful. Roesler (1952) also found that it is possible to effect a transfer from pears to apples, and vice-versa. In view of this result, it was not necessary to carry out a transfer to all fruit varieties in the following tests, and the transfer to apples was regarded as being valid for all the other fruit varieties.

Table 26: Transfer test between apple, *Prunus spinosa* and *Malus Scheidekeri*.

| from                     | Apple | <i>Prunus spinosa</i> | <i>Malus Scheidekeri</i> |
|--------------------------|-------|-----------------------|--------------------------|
| to                       |       |                       |                          |
| Apple                    | +     | +                     | +                        |
| <i>Prunus spinosa</i>    | +     | +                     | +                        |
| <i>Malus Scheidekeri</i> | +     | +                     | +                        |

+ = Transfer successful, normal development and reproduction.

Table 26 shows that the transfer of mites from *Prunus spinosa* and *Malus Scheidekeri* was successful. The significance of both plant hosts as infectors for the colonization of fruit trees is quite obvious when it is considered that the population density of *Br. praetiosa* is always high on both of them. The investigations of Unterstenhöfer (1955) and my own studies revealed that *Prunus spinosa* is also a plant host to *P. pilosus*. In view of the fact that



buckthorn is a widespread shrub found at the edges of woods, in brush and in underwood in Northern Germany, *Prunus spinosa* must be regarded as an important infector. Unterstenhöfer (1955) points out that due to the occurrence of such plant hosts, there must be much doubt as to the value of hedges in fruit growing.

Further transfer tests were carried out between the different groups of plant hosts.

**Method:** Very seriously infested plant species were selected from the different groups for the purpose of these tests. The transferred insects originated from apples (first group), gooseberries (second group), hawthorn (third group), ivy (fourth group), *Lolium perenne* and *Ranunculus repens* (fifth group). In the case of apples, gooseberries, ivy and *Lolium perenne*, potted plants were infected and it was only with hawthorn that the transfer was effected to single leaves.

Table 27: Transfer test between the groups of plant hosts.

|                       | 1st Group<br>from Apple | 2nd Group<br>Gooseberry | 3rd Group<br>Hawthorn | 4th Group<br>Ivy | 5th Group<br><i>L. perenne</i><br><i>R. repens</i> |
|-----------------------|-------------------------|-------------------------|-----------------------|------------------|----------------------------------------------------|
| to                    |                         |                         |                       |                  |                                                    |
| Apple                 | +                       | —                       | —                     | —                | —                                                  |
| Gooseberry            | —                       | +                       | —                     | —                | n. i.                                              |
| Hawthorn              | —                       | —                       | +                     | n. i.            | n. i.                                              |
| Ivy                   | —                       | —                       | —                     | +                | —                                                  |
| <i>Lolium perenne</i> | —                       | —                       | —                     | —                | +                                                  |

+ = Transfer successful, normal development and reproduction.

— = Transfer unsuccessful, no normal development and no reproduction.

n. i. = not investigated.

The transfer between the different groups of plant hosts was a failure in all cases. The mites transferred from gooseberries and ivy to apples at first consumed food on the new plant host but after a short time they either died or attempted to migrate.

Accordingly, only the plant species belonging to the first group of plant hosts can act as infectors for the colonization of fruit trees by *Br. praetiosa*. It is quite likely that the range of plant hosts acting as infectors for the colonization of fruit trees can be expanded because it was only possible to include in the investigations those hosts discovered in the Rhenish-Bergisch district. Particular attention must be given to plants growing close to orchards, and on which the development of the mites, if infested by *Br. praetiosa*, is the same as on fruit trees.

## IX. Control

The successful prevention of damage by spider mites in orchards can only be realized under present-day conditions by applying chemical control preparations. As a species-specificity to insecticides exists among spider mites (Unterstenhöfer 1955), it had to be established which known acaricides are also effective against *Br. praetiosa*. Furthermore, the question was also investigated whether it is possible to control *Br. praetiosa* and *P. pilosus* simultaneously, both with respect to the date of control and also with respect

to the effective range of the acaricide. In view of the frequency at which both species occur together in orchards, it is of great importance to clarify this question in order to place plant protection measures on a sound economic basis.

### A. Dates of Control

During the course of the year, either winter eggs only, post-embryonic stages only, or eggs and post-embryonic stages together occur on the fruit trees (Fig. 19). Therefore, a control can be directed against

1. The winter eggs during vegetation dormancy;
2. The population consisting solely of post-embryonic stages when all the larvae have hatched out of the winter eggs but before any summer eggs have been laid;
3. The population consisting of eggs and post-embryonic stages, from the commencement of summer egg-laying until the end of the infestation by the post-embryonic stages in Autumn.

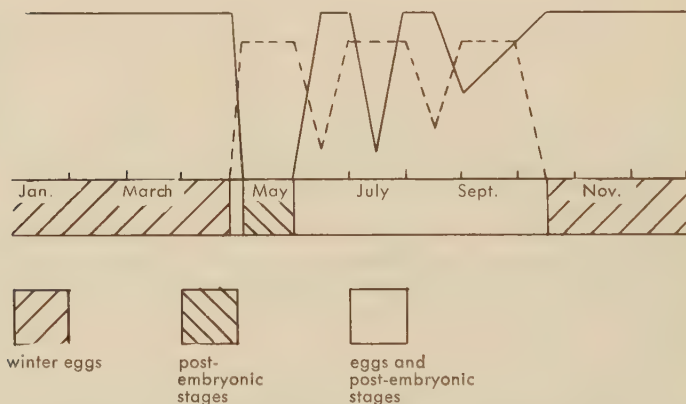


Fig. 19: Seasonal occurrence of development stages (eggs and post-embryonic stages) of *Br. praetiosa*

— eggs  
- - - post-embryonic stages

Fundamentally, the same dates of control apply to *P. pilosus* (Unterstenhöfer 1954).

To 1: The control of the winter eggs of *Br. praetiosa*, which as shown in Fig. 19 is possible between Autumn and Spring, ought to be carried out as part of the winter spray programme.

This control cannot produce the expected degree of success for two reasons:

- a) The observation made by Friedrich (1951) and Unterstenhöfer (1954) in respect of *P. pilosus*, that it is practically impossible due to concealed oviposition, to spray all the eggs with the insecticide, applies to an

even greater extent to *Br. praetiosa* because the latter species lays far more winter eggs at protected sites on the lower surface of the branches than does *P. pilosus*. The result of the control will not be satisfactory even when effective ovicides are applied particularly as winter sprays should be carried out in the direction of the wind whereas the winter eggs are chiefly laid on that side of the tree away from the wind (Friedrich 1951).

- b) Regular winter sprays have caused spider mite infestations to increase in many orchards. The reason for this appears to be that the sprays kill the predators of the spider mites (Massee and Steer 1929; Geijkes 1938, Wiesmann 1940; Loewel and Reich 1952).

Unterstenhöfer (1954) is of the opinion that the winter sprays are especially valuable when there is a heavy rate of oviposition so that the damage inflicted by the first generation can be reduced. He emphasizes, however, that when conditions are favourable for development, it will be necessary to carry out a summer control even though the winter sprays may have been most effective. This observation made in respect of *P. pilosus* also applies to *Br. praetiosa*.

The unsatisfactory results produced by spider mite controls are chiefly responsible for present-day scepticism towards winter spraying (Bachmann 1954; Schneider 1952; Loewel and Reich 1952).

To 2: The second date of control is in Spring when all the winter eggs are empty but before any summer eggs have been laid (Fig. 19). A comparison of hatching dates (Table 3) with the dates when the fruit trees bloom, will show that as a rule the larvae of *Br. praetiosa* already hatched out before the trees flower so that a pre-blossom spray can be carried out against the post-embryonic stages.

This early date of control is particularly favourable because in consequence the damage caused to the first stages by mites of the first generation can be avoided. It should be remembered that prevention of this damage is of great importance for the vegetative and generative development of the fruit tree, in particular for the fruit setting of the particular year (Unterstenhöfer 1955).

When controlling the post-embryonic stages, it is essential that the development stages of *Br. praetiosa*, and in particular the quiescent stages, are present on the branches of the fruit trees. Moreover, it is also essential to wet the branches thoroughly with spray wash if good results are to be obtained. The application of preparations which possess a residual effect will give an even greater guarantee that all stages are killed. By applying such preparations, the quiescent stages which are not touched by spray wash on the branches, will also be killed when they migrate to the leaves in search of food at the end of their quiescence. In order to carry out a joint control of *Br. praetiosa* and *P. pilosus* at this time, it is important to know that both species commence laying their summer eggs at the same time despite the fact that *Br. praetiosa* starts to hatch out earlier (Table 3). The most favourable date for carrying out a joint control of both spider mite species therefore depends chiefly upon when the larvae of *P. pilosus* hatch out of the winter eggs (Unterstenhöfer 1955), so that the date for controlling *P. pilosus* can be fixed solely according to official recommendations given by regional plant protection offices.

To 3: A third possibility for carrying out a control is between the start of summer egg-laying and the end of post-embryonic infestation in Autumn (Fig. 19).

Allowance must be made for the following difficulties during this period:

- a) Due to the varying degree of susceptibility of the different development stages to acaricides, either only the eggs or only the post-embryonic stages will be killed. Consequently only a part of the population will be eradicated. Preparations having a residual effect will also give control of those stages entering a susceptible stage during the period the insecticide is still persistent. Nevertheless, it is only by repeating the sprays that an adequate degree of success can be obtained.
- b) Many of the summer eggs are also laid in concealed places on the lower surface of the branches so that even very effective ovicides will not give satisfactory results.
- c) The very important damage caused to the first leaves will not be prevented.

The disadvantages given in a) and c) also apply to *P. pilosus*.

Therefore a control of a population consisting of eggs and post-embryonic stages should only be carried out in exceptional cases when the density of infestation increases greatly during the course of the summer months. In this case, the most favourable date for carrying out a control directed only against *Br. praetiosa* will be when there are few eggs present on the trees (Fig. 13), and use should be made only of preparations which have a residual effect.

## B. Trial Controls of the Egg Stage

I made use of the well-known winter sprays and several other acaricides in order to test the ovicidal effect against winter eggs of *Br. praetiosa*. Against the summer eggs, use was made only of preparations which can be applied during the vegetation period and which were assumed to be effective also against the post-embryonic stages of *Br. praetiosa* on the basis of their more or less good efficacy against other spider mite species.

The tests conducted were only of an informative nature. In order to facilitate an exact evaluation of the tests, conditions were selected which permitted better results than are normally obtained in field treatments of fruit trees.

### 1. Winter eggs

A laboratory test and a field trial were conducted to test the ovicidal effect against winter eggs of *Br. praetiosa*.

#### Method:

##### a) Laboratory test

Pieces of branches colonized by winter eggs of *Br. praetiosa* were transferred from outdoors to the laboratory where they were immersed in solutions of the preparations being tested. The eggs were glued to the wooden board by means of the method described earlier, and kept in the laboratory at a temperature of 20° C. After the hatching process had started, a count was taken of the number of larvae that emerged daily. The percentage of hatching was calculated at the end of the hatching-out process. The test was conducted with four replications.

##### b) Combined laboratory and field test

Branches colonized by winter eggs of *Br. praetiosa* were sprayed on the fruit tree with the preparations being tested. As it was not possible to take an exact count of



the number of larvae which emerged outdoors, the treated branches were transferred to the laboratory shortly before the start of hatching, and glued to a wooden board. The number of larvae that hatched out was counted daily, and the percentage was calculated at the end of the hatching-out process. This test was also conducted with four replications.

The results of these tests are given in Tables 28 and 29.

There was a high degree of conformity between the results obtained in the laboratory tests and those produced by the field trials. Dinitro-o-cresol was the only actual winter spray to give a high percentage of eradication. This preparation however is not particularly suitable for a joint control of *Br. praetiosa* and *P. pilosus* because Andersen (1948) only established a slight effect against the winter eggs of *P. pilosus*.

## 2. Summer eggs

**Method:** Pieces of branches colonized by summer eggs of *Br. praetiosa* were transferred from outdoors to the laboratory where they were immersed for 10 seconds in the corresponding solutions of the preparations being tested. The pieces of branches were then glued to a wooden board, and surrounded by a vaseline ring. They were kept outdoors in order to expose the treated eggs to weather influences. The number of larvae that hatched out was counted twice daily in the laboratory under the binocular lens, and the percentage of larvae that emerged was calculated at the end of the hatching-out process. The test was conducted with four replications.

The results are given in Table 30.

Table 28: Percentage of *Br. praetiosa* winter eggs eradicated by different preparations (laboratory test).

|                                     | Number<br>of eggs | Number<br>hatched | Percentage<br>eradicated |
|-------------------------------------|-------------------|-------------------|--------------------------|
| Fruit tree carbolineum<br>8 %       | 270               | 217               | 19.6 ± 6.2               |
| DNOC tar oil<br>4 %                 | 177               | 168               | 5.1 ± 1.3                |
| Dinitro-o-cresol<br>1 %             | 185               | 10                | 94.5 ± 2.3               |
| "Folidol-E 605"<br>0.035 %          | 182               | 167               | 8.2 ± 2.3                |
| "Systox"<br>0.05 %                  | 215               | 176               | 18.2 ± 5.3               |
| Chlorobenzilate<br>0.1 %            | 245               | 214               | 12.6 ± 4.1               |
| Ovotran<br>Emulsion<br>0.7 %        | 283               | 8                 | 97.1 ± 0.8               |
| Ovotran<br>Wettable Powder<br>0.1 % | 193               | 139               | 28.0 ± 6.9               |
| Check                               | 243               | 235               | 3.3 ± 0.9                |

Table 29: Percentage of *Br. praetiosa* winter eggs eradicated by different preparations (combined laboratory and field test).

|                        | Number<br>of eggs | Number<br>hatched | Percentage<br>eradicated |
|------------------------|-------------------|-------------------|--------------------------|
| Fruit tree carbolineum |                   |                   |                          |
| 8 %                    | 212               | 199               | $6.1 \pm 3.5$            |
| Dinitro-o-cresol       |                   |                   |                          |
| 1 %                    | 225               | 14                | $94.0 \pm 1.7$           |
| "Folidol-E 605"        |                   |                   |                          |
| 0.035 %                | 194               | 181               | $6.7 \pm 1.1$            |
| "Systox"               |                   |                   |                          |
| 0.05 %                 | 250               | 212               | $15.2 \pm 4.7$           |
| Chlorobenzilate        |                   |                   |                          |
| 0.1 %                  | 229               | 202               | $11.8 \pm 4.3$           |
| Ovotran                |                   |                   |                          |
| Emulsion               |                   |                   |                          |
| 0.7 %                  | 243               | 12                | $95.0 \pm 1.1$           |
| Ovotran                |                   |                   |                          |
| Wettable Powder        |                   |                   |                          |
| 0.1 %                  | 207               | 189               | $8.7 \pm 3.2$            |
| Check                  | 196               | 187               | $4.6 \pm 2.3$            |

Table 30: Percentage of *Br. praetiosa* summer eggs killed by different preparations.

|                  | Number<br>of eggs | Number<br>hatched | Percentage<br>eradicated |
|------------------|-------------------|-------------------|--------------------------|
| Wettable sulphur |                   |                   |                          |
| 0.5 %            | 306               | 282               | $7.9 \pm 4.5$            |
| "Folidol-E 605"  |                   |                   |                          |
| 0.035 %          | 289               | 226               | $21.8 \pm 1.4$           |
| "Systox"         |                   |                   |                          |
| 0.05 %           | 257               | 104               | $59.5 \pm 6.6$           |
| "Metasystox"     |                   |                   |                          |
| 0.1 %            | 246               | 196               | $20.3 \pm 3.3$           |
| "Chlorthion"     |                   |                   |                          |
| 0.1 %            | 292               | 219               | $25.0 \pm 4.8$           |
| Chlorobenzilate  |                   |                   |                          |
| 0.1 %            | 324               | 272               | $16.1 \pm 2.2$           |
| Aramite          |                   |                   |                          |
| 0.2 %            | 205               | 167               | $18.5 \pm 5.3$           |
| No. 4536         |                   |                   |                          |
| 0.05 %           | 261               | 213               | $18.4 \pm 2.8$           |
| No. 4551         |                   |                   |                          |
| 0.2 %            | 261               | 0                 | $100.0 \pm 0.0$          |
| Check            | 365               | 344               | $5.8 \pm 1.8$            |

The only preparation to kill all the summer eggs was No. 4551. The other preparations did not give a satisfactory effect. It was observed in the case of chlorobenzilate that some of the larvae which hatched out of the treated eggs died after a time. This means that the effect of chlorobenzilate is better than the test result would suggest.

### C. Trial controls of post-embryonic stages

The trial controls of the post-embryonic stages were also of an informative nature because they were not carried out on the fruit trees but on shoot tips stocked in the field laboratory, which were not exposed to the influence of rain.

**Method:** Shoot tips colonized by all stages of *Br. praeitiosa* were immersed in solutions of the preparations being tested, and then placed in Erlenmeyer flasks filled with water. The stalks were coated with a ring of vaseline to prevent the mites from migrating. The shoot tips were kept in the field laboratory.

The percentage of knock-down was estimated 1, 2 and 7 days after the treatment. In order to obtain information as to whether the preparations had a specific effect, the larval, nymph and quiescent stages and the imagoes were evaluated separately.

The results of the tests are given in Tables 31 and 32.

Table 31: Percentage of knock-down of post-embryonic stages by different insecticides.

|                    | Knock-down in larval and nymphal stages |              |        | % of quiescent stages |
|--------------------|-----------------------------------------|--------------|--------|-----------------------|
|                    | 1 day                                   | after 2 days | 7 days | after 7 days          |
| Wettable sulphur   |                                         |              |        |                       |
| 0.5 %              | 10                                      | 20           | 20     | 0                     |
| "Folidol-E 605"    |                                         |              |        |                       |
| 0.035 %            | 90                                      | 95           | 100    | 100                   |
| "Systox"           |                                         |              |        |                       |
| 0.05 %             | 100                                     | 100          | 100    | 100                   |
| "Metasystox"       |                                         |              |        |                       |
| 0.1 %              | 90                                      | 100          | 100    | 100                   |
| "Chlorthion"       |                                         |              |        |                       |
| 0.1 %              | 80                                      | 70           | 50     | 0                     |
| Chlorobenzilate    |                                         |              |        |                       |
| 0.1 %              | 90                                      | 90           | 80     | 60                    |
| Ovotran (Emulsion) |                                         |              |        |                       |
| 0.7 %              | 80                                      | 50           | 50     | 30                    |
| Aramite            |                                         |              |        |                       |
| 0.2 %              | 40                                      | 50           | 70     | 80                    |
| No. 4536           |                                         |              |        |                       |
| 0.05 %             | 90                                      | 100          | 100    | 100                   |
| No. 4551           |                                         |              |        |                       |
| 0.2 %              | 95                                      | 100          | 100    | 100                   |
| Check              | 0                                       | 10           | 10     | 0                     |

Table 32: Percentage of knock-down of imagoes by different insecticides.

|                    | Knock-down of imagoes in % |                 |        |
|--------------------|----------------------------|-----------------|--------|
|                    | 1 day                      | after<br>2 days | 7 days |
| "Folidol-E 605"    |                            |                 |        |
| 0.035 %            | 30                         | 50              | 100    |
| "Systox"           |                            |                 |        |
| 0.05 %             | 100                        | 100             | 100    |
| "Metasystox"       |                            |                 |        |
| 0.1 %              | 100                        | 100             | 100    |
| "Chlorthion"       |                            |                 |        |
| 0.1 %              | 90                         | 90              | 60     |
| Chlorobenzilate    |                            |                 |        |
| 0.1 %              | 40                         | 40              | 50     |
| Ovotran (Emulsion) |                            |                 |        |
| 0.7 %              | 10                         | 50              | 70     |
| Aramite            |                            |                 |        |
| 0.2 %              | 50                         | 70              | 80     |
| Check              | 0                          | 0               | 10     |

Several of the tested insecticides killed all the post-embryonic stages of *Br. praeitiosa* whereas a comparison of the effects obtained against eggs, post-embryonic stages and imagoes reveals that there are definite differences between embryonic susceptibility, on the one hand, and post-embryonic susceptibility, on the other hand. Consequently, control measures directed against eggs and post-embryonic stages on the trees are effective only against a part of the population whereas they produce good results when only post-embryonic stages are present on the trees at the time of the treatment.

## X. Summary

The object of the investigations was to obtain further data to supplement that available on the biology, epidemiology and control of *Br. praeitiosa* Koch.

### A. Biology

1. *Br. praeitiosa* is widespread over large areas of the moderate zones, and is a typical pest of extensive agricultural plantations.
2. The larvae begin to hatch out of the winter eggs in April under the climatic conditions prevailing at the Höfchen Research Station, as a rule 1 to 2 weeks before the larvae of *P. pilosus* emerge; the hatching-out process is completed before the fruit trees bloom. The date of



hatching can be pre-determined by transferring the winter eggs to the laboratory.

3. The date of hatching, the period of hatching and the number of larvae hatching out daily are factors all influenced by the temperature. The greatest percentage of larvae hatched out of the winter eggs at temperatures ranging from 19 to 27° C, whereas lower and higher temperatures caused a decrease in the hatching rate. In fact, no more larvae hatched out at temperatures above 33° C. The percentage of emergences decreased from 90.8 % at 5 % relative humidity to 75.4 % at 96 % relative humidity. Differences in the exposure of the eggs to light had no influence upon the rate of hatching.
4. The development period of the post-embryonic stages and the length of the pre-ovipositional period were shorter outdoors than in the laboratory. The quiescent stages took longer to develop than the larval and nymphal stages. *Br. praetiosa* take longer to develop than *Tetr. althaeae* and *P. pilosus*.
5. In contrast to *P. pilosus*, *Br. praetiosa* proved to be relatively resistant to extremely high temperatures. *Br. praetiosa* suffered much more than *P. pilosus* on moist leaves. *Br. praetiosa* can be regarded as a species which displays a liking for dry conditions and which is compatible with heat.
6. *Br. praetiosa* overwinters in the egg stage under the climatic conditions prevailing at the Höfchen Research Station. Three generations were studied in 1954 and 1955, and it was established that the first generation laid only summer eggs, the second generation winter and summer eggs, while the third generation laid only winter eggs.
7. Summer eggs are deposited on leaves and branches whilst winter eggs are laid only on branches especially at protected sites on the lower surface. The number of eggs laid drops from the 1st to the 3rd generation; *Br. praetiosa* lays fewer eggs than *Tetr. althaeae* and about as many as *P. pilosus*.
8. The embryonic development of *Br. praetiosa* lasts considerably longer than that of *Tetr. althaeae* and *P. pilosus*. The zero point of development is between 3 and 6° C.
9. The post-embryonic stages of *Br. praetiosa* occur sometimes on the leaves and occasionally on the branches. The location at which the mites occur is presumably influenced chiefly by varying feeding conditions during the course of the vegetation period. Temperature and rainfall may also exert a temporary influence.

## B. Epidemiology

1. The number of generations produced depends upon the date when the larvae start to hatch out in Spring, upon the weather and upon the feeding conditions. 3 generations were produced in 1954, whereas in 1955 there were also 3 generations under unfavourable feeding conditions and four under favourable conditions.
2. The main influence upon the change in population density of *Br. praetiosa* is exerted by the weather conditions. In 1954, a decrease in the infestation density from the 1st to the 2nd generation was established

under unfavourable weather conditions whereas in 1955 the conditions were favourable thus leading to an increase in the infestation density between the first two generations. The third generation had the smallest population density in both test years, and was influenced both by the weather and by the feeding conditions and predators. The same factors also exert a considerable influence upon the number of winter eggs laid.

3. The development potential of *Br. praetiosa* is not so great as that of *Tetr. althaeae*, and differs from *P. pilosus* in the smaller number of generations and greater percentage of females. *Br. praetiosa* and *P. pilosus* can be classified as early pests, whereas *Tetr. althaeae* is a late pest.
4. Transfer trials confirmed that *Prunus spinosa* L. and *Malus Scheidekeri* Zabel are important infectors for the colonization of fruit trees by *Br. praetiosa*.

## C. Control

Trial controls showed that the preparations which were tested were only slightly effective against the winter and summer eggs of *Br. praetiosa* whereas several insecticides eradicated the entire post-embryonic stages. A maximum of success appears to be assured by carrying out a control in Spring during the occurrence of a population consisting only of post-embryonic stages.

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